RURAL ASIA-PACIFIC:

INTER-DISCIPLINARY STRATEGIES TO COMBAT HUNGER AND POVERTY

Rice-based livelihood-support systems

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Regional Office for Asia and the Pacific
Bangkok, Thailand

RAP publication 2002/12

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Preface

This document features the Asia-Pacific rice-based livelihood systems. It is the first of five compilations that describe new inter-disciplinary strategies wherewith to combat hunger and poverty in rural Asia-Pacific. The four companion documents respectively feature *Biotechnology, biosecurity, and biodiversity; World trade and an enabling policy environment; Livestock intensification; and Disasters preparedness and management.*

The Asian ricelands have an annual harvest area of about 135 million hectares, and are tended by nearly 300 million persons. They support 3 billion rice consumers: one-half of the world's population, and about two-thirds of its hungry and poor. For most of those consumers, rice supplies at least one-third of their dietary energy, and in some rice-growing countries three-fourths. The ricelands are a unique and recognizable entity, and have sufficient commonality that successful practices can be widely replicated. During the past four decades they have helped lessen hunger and poverty, and sustain livelihoods. Nonetheless, within them there still persists much hunger and poverty.

The three dominant food-security cereals - rice, wheat, and maize - have very similar global productions of about 600 million tonnes per year. Within those global totals, the Asia-Pacific region produces nine-tenths of the rice, compared to one-third of the global wheat, and one-fourth of the maize (mostly for livestock feed). In dietary terms, as also in social, economic, and ecological terms, the contributions of the non-rice crops and of livestock are in the major rice-growing countries dwarfed by those of rice.

There are responsible forecasts for the substantially increasing requirements for rice during 2003-2015-2030, and responsible expectations that widespread adoption of current and emerging best-practice production procedures can meet those requirements, and can do so with a diminishing demand on biophysical and human resources. The resources thus spared from food-security rice production shall allow diversification of rice-based farming systems and of income-generating enterprises.

Other extensive food-and-livelihoods systems in East and South Asia are the *upland* and the *highland* mixed farming systems. They, like the rice systems, are home to many poor persons, and contribute to those persons' food security; appropriate programmes are needed for these upland systems. However, and without gainsaying the needs of other Asian farming systems, this document addresses *only* the rice-based farming systems, with their rice and non-rice crops, their livestock and fish, and their value-adding employment-creating enterprises, and their unique submerged-soil ecological regimes and biodiversity, and their environmental challenges for water (for which many competing demands) and for the safe and efficient use of agro-chemicals.

In combination, the preceding Asian and global considerations illustrate the extent to which global food security (particularly of poor persons) is determined by the rice security of Asia, and by the products of its rice-based systems. Systems that are so large and so pro-poor as the rice systems have major potential to impact - favourably or adversely - on the world's food security and on its politico-economic stability.

This document thus reviews the role of the rice-based systems in sustaining human livelihood and food security. It identifies a vision, goals, and livelihood-oriented activities in rice-system production and products utilization and in institutional support. Noting that progress towards Year-2015 food-security and poverty-alleviation targets has been less than required, it suggests that part of the cause is the substantial decline in global assistance to developing-world agriculture during 1989-99, and that part of the remedy is to increase and sustain investments in physical and human resources for developing-world agriculture - particularly for rice-based agriculture. The document's purpose is to engender within an influential readership a heightened awareness of the key features, global importance, and pressing needs of these vital systems, and to suggest that those needs might best be addressed through multi-stakeholder, multi-disciplinary endeavours.

For the rice-family livelihoods, there are many constraints and challenges to the lessening of hunger and poverty and to the improvement of lifestyles - particularly for children and adolescents. Encouragingly, recent economic growth forecasts permit optimism that there shall in most rice-growing countries be increased national resources wherewith to combat rice-system hunger and poverty. There is also growing commitment that globalization of trade can and must be made to work for the hungry and poor. Helpfully, in addressing the constraints and challenges, the ricelands' human, economic, institutional, technological and biophysical resources are now substantially stronger than in recent decades. Notably, the ongoing expansion of education and extension shall ensure that the future rice-system families shall be better prepared than their predecessors

to take advantage of more complex technologies, concepts, and systems, and to recognize pertinent opportunities. To avail of these opportunities, there must be appropriate policies for smallholder agriculture, for agricultural trade (national and globalized), for price supports and damaging subsidies, for resource management, and for enabling rural women to attain equitable access to income generating resources.

This document therefore proposes livelihoods-oriented interventions to assist riceland families to use their existing strengths to escape from hunger and vulnerability. It recognizes that investment in women is crucial in achieving food security and poverty reduction. It suggests that intervention strategies should be based on current best practices. Strategies recognize also that although irrigated rice systems shall contribute most of the increased food production to ensure food security, high priority is now accorded to the non-irrigated ricelands in expectation of substantially lessened poverty per unit investment. In many ricelands there shall be opportunities to use the Rice-Check Package in combination with Yield-Gap Methodology, and to avail of crop-livestock synergies, and to support women-operated quality seed production enterprises. Additionally, rice-system crops and livestock each provide within-community value-adding and employment-creation opportunities, particularly for women. Rice, and its by-products, and native chicken and hybrid duck and dairy cattle products, all offer income generating options. For some ricelands, sequestration of carbon and production of bio-fuel crops for electricity generation may be viable Agenda-21 and Kyoto-Protocol options.

This document thus proposes 33 candidate rice-community interventions, characterized as technological, or as socio-economic, or as institutional, policy and infrastructural - all to be implemented integratively. However, integrated development demands attention to education, health care, infrastructures and micro-finance. Interventions should thus be implemented holistically through a multi-stakeholder, multi-disciplinary coalition that includes the riceland communities, civil society organizations, national ministry components, UN agencies including FAO, and others. The candidate interventions are presented as “a menu” from which choices would be made by member governments, thereby ensuring congruence with their national food-security/poverty-alleviation programmes, and with the specific needs of their targeted riceland communities.

There will similarly be enquiry among prospective donors and stakeholder partners in this proposed endeavour. The document thus specifies the outputs that would be expected from the candidate interventions. FAO would be a participant in much of this intervention and its monitoring, and would help catalyse the contributions of the many stakeholders - including UN agency stakeholders. Indeed, collaborative action by several UN agencies would permit that interventions could be undertaken within the mandates of the UN Development Group and within the multi-UN Agency Network on Rural Development and Food Security.

Notwithstanding many challenges to the improvement of rice-systems livelihoods - particularly for the poorest of the poor and for hungry children - we might plead that the required investments are not immense. Such investment can help poor families to make their own way out of hunger and poverty. FAO is well positioned to initiate and support the required multi-agency endeavours. Such endeavours can help provide to disadvantaged children and adolescents a better quality of life than that experienced by their parents. Investments made now might well obviate the need for a later and more-costly crisis management.

This publication derives from analyses undertaken by the authors at the Asia-Pacific Regional Office of the Food and Agriculture Organization of the United Nations. The authors thank the many technical colleagues from that office for helpful comments and discussion.

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Executive summary

Asia-Pacific's rice-based systems: their importance for rural livelihoods

This document reviews the role of Asia's rice-based systems in sustaining human livelihood and food security. It identifies a vision, goals, and livelihood-oriented programmes for key activities in rice-system production and products utilization - for rice, non-rice crops and livestock - and in institutional supports. It highlights how progress towards the Year-2015 food-security and poverty-alleviation targets has been less than required, and suggests that this disappointing progress is in part the result of the substantial decline in global assistance to developing-world agriculture during 1989-99.

The document's purpose is to engender within a knowledgeable and influential readership a heightened awareness of the key features, global importance, and pressing needs of these systems. The document recognizes that rice-family livelihoods depend not on food supply alone, but on interactions of social, economic, and natural-resource endowments. It correspondingly acknowledges that those pressing needs of the riceland systems might best be addressed through multi-stakeholder, multi-disciplinary endeavours.

The Asia-Pacific ricelands extend from the Solomon Islands and Japan in the east to Pakistan and Iran in the west. They have an annual rice-harvest area of about 140 million hectares (Mha); they nurture 200 million bovine livestock, and rather fewer small ruminants. They are tended by nearly 300 million persons, and support 3 billion rice consumers: one-half of the world's population, and more than one-half of its hungry. The aggregation and contiguity of the systems is globally unique. During 5 000 years, the bunded, terraced ricefields have allowed a sustainable use of land and of high-intensity rainfall.

For several countries within the contiguous belt rice has cultural and political dimensions. In dietary terms, as in social, economic and ecological terms, the contributions of non-rice crops and of livestock are in the major rice-growing countries dwarfed by those of rice.

There are responsible forecasts for the increasing requirements for rice during 2003-2030, and responsible expectations that widespread adoption of current and emerging best-practice production procedures can meet those requirements, and can do so with diminishing demand on biophysical and human resources. The resources spared from rice production shall allow diversification of rice-based farming systems and of income-generating enterprises.

The ricelands and their rice-buffer stocks shall during 2003-2030 have a year-on-year increasing requirement to supply about 600 Mt rice / annum. If during a succession of years the supply should be inadequate, and with a rest-of-the-world rice production of only 60 Mt / ann, the task of substituting any substantial shortfall by alternative foods shall be immense. Indeed, global food security is to large extent determined by the rice security of Asia, and by the products of its rice-based systems. A system that is so large and so pro-poor as the rice system has major potential to impact - favourably or adversely - on the world's food security and on its politico-economic stability.

Other extensive food-and-livelihoods systems in East and South Asia are the upland and the highland mixed farming systems. They, like the rice systems, are home to many poor persons, and contribute to those persons' food security. Appropriate programmes are needed for these upland systems. However, and without gainsaying the needs of other Asian farming systems, this document addresses only the rice-based farming systems, with their rice and non-rice crops, their livestock and fish, and their value-adding employment-creating enterprises, and their submerged-soil ecological regimes, bio-diversity, and environmental challenges.

The rice systems helped lessen hunger and poverty, and to sustain livelihoods. Thus, in East-plus-South Asia, adequately nourished persons increased in number from 1.12 B (billion) in 1970 to 2.56 B in 1996. Incomes doubled during 1970-2000; the number of non-poor persons increased from 1.80 B in 1970 to 2.37 B in 1998. However, hunger and poverty still persist in Asian rice growing countries.

Quantifying poverty: in East Asia at 1990, poor persons comprised 28 percent of the total population, but at 1998 only 15 percent. Correspondingly for South Asia: 44 and 40 percent. Nonetheless, in East-plus-South Asia there are still 800 million poor persons: two-thirds of the world's poor.

For human nourishment: at 1996 there were in East-plus-South Asia no fewer than 2560 million adequately nourished persons (83 percent of the total population). Conversely, the number of undernourished, 524 millions, is almost two-thirds of the 791 million total, and is intolerably high.

Rice systems are characterized by water regime: irrigated, rainfed lowland, floodprone, and rainfed upland. Irrigated land constitutes 56 percent of the total area: it generates more than 75 percent of total rice production. Because irrigated-land production is more stable year-to-year than non-irrigated-land production, it has higher benefit for food security.

Among various rice-based cropping sequences, rice-rice-based and rice-wheat-based farming are prominent among FAO's generic farming systems. Within each generic system, there is sufficient commonality of conditions that system-wide strategies for livelihoods-enhancing interventions can be formulated, and appraisals made among candidate strategies to lessen hunger and poverty.

Within the Asian ricelands, seventeen countries annually harvest at least 0.6 Mha of rice. They have an aggregate population of 3.2 billion persons; they comprise: Bangladesh, Cambodia, China, India, Indonesia, Iran, DPRKorea, RoKorea, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Viet Nam. No fewer than eleven of them are classified as low-income food-deficit. Twelve of them fall within the two most severe categories of prevalence-plus-depth of hunger. Ten of them have at least 10 percent of their riceland as rainfed lowland, and/or rainfed floodprone (deepwater), and/or rainfed upland.

For fifteen of the seventeen countries, rice supplies more than one-third of dietary energy and protein; and among that fifteen, for eight of them more than one-half, and for four of those eight, about three-fourths. With five exceptions, average values for k-calories/person.day are for the seventeen countries sufficient to satisfy national dietary energy supply. However, seven countries have very high rates of moderate to severe infant undernourishment.

Rice production per person ranges from 40 kg/person.ann (Iran, Pakistan) to 390 kg/person.ann for the major rice exporters. Maize, oil-crops, fruits, and vegetables are in most rice producing countries increasing in production more quickly than rice and than human populations. The maize and oil-crops are meeting increasing demands both for human food and for livestock feed. Most of the countries import appreciable quantities of wheat products.

Several of the rice-growing communities and countries are substantial producers of livestock products. In some rice-based systems there is a small but valuable contribution of protein and income from fish.

Among rice-system inputs, mechanization is furthest developed in the extreme east and in the extreme west. In some countries, (mineral) fertilizer application rate is sufficiently high that there is risk of adverse environmental impacts; in others, so low as to limit rice and non-rice crop production. Rice-land environmental concerns relate particularly to water and to agro-chemicals. The abstraction of groundwater for irrigation depletes aquifers. Misapplication of pesticides results in damage to non-target organisms.

Smallholdings, including rice holdings, contribute substantially to food security. National economics, trade, and policy impact on rice-family livelihoods. The ratio of agricultural employment to total employment is for all countries substantially higher than the ratio of agricultural GDP to total GDP. There is thus need to redirect resources, investments, and policies if rural impoverishment and underemployment are to be lessened.

Thailand, Viet Nam, India and Pakistan - in that order - are the major consistent rice exporters. Rice imports into rice-growing countries respond to individual years' circumstances. Inception of the World Trade Organization was followed, for most rice-growing countries, by an increased share of international agricultural trade. However, for most of those countries, imports increased more than exports.

For rural livelihoods, some analyses suggest that national structural adjustment programmes worsened the food security of poor rural families. Other analyses suggest that integration into the world economy has resulted in higher growth in incomes, longer life expectancy and better schooling.

Regional and sub-regional trends and projections

The global developing-country demand for rice shall progress as 540, 665, and 765 Mt/ann (million tonnes per annum) at 1996, 2015, and 2030. This increased demand for rice (and rice-system products) is driven by population growth and moderated by dietary changes; for many countries, the rice/person.ann requirement

shall stabilize at Year-2000 values. Nonetheless, average rice yield shall need to increase from 3.5 to 4.6 t / ha during 1996 - 2030: implying growth rates during 1996-2015 and 2015-2030 as 1.2 and 0.6 % / ann, compared to 2.3% / ann achieved during 1975-95. Indeed, past achievement has lessened the requirement for high annual growth in food energy per person. There shall in fact be a strong deceleration in the need for increased food production; but a much-increased demand for livestock feeds and livestock products.

Correspondingly, the challenges to the productive capability of the rice-based food systems shall be less severe than the challenges that were overcome during the past thirty years. In addressing those challenges, the dominant source of growth in production in East and in South Asia shall be increased yields. Fortunately, the available bio-physical, human, technological and economic resources are greater than heretofore.

Thus, although rice area per person decreased during 1961- 98 from 0.12 to 0.07 ha/person, and may continue to decrease, increased productivity and income per unit of land shall compensate for that decrease. Irrigated-area shall increase during 1996-2030, and efficiency of irrigation-water distribution and allocation shall increase also.

Global applications to rice of manufactured nutrients at 1996, 2015 and 2030 are estimated as 22.2, 26.3 and 27.6 Mt / ann. N-applications to Asian rice shall increase substantially. Against rice-system pests and adverse soil-and-climate constraints, technological developments should be able to contain losses. In all rice systems, post-harvest crop losses can be substantial. Notably, investments in non-irrigated lowland-rice systems may contribute both to cost-effective increase in rice production and to a lessening of poverty and environmental degradation. For genetic resources, current rice-yield surveys report definitively that "on 75 Mha of irrigated rice farms there is no evidence of rice-yield decline". However, from new analyses using six-year time segments there are concerns that rice-yield growth rate may have slackened more than was previously realized. For long-term research-experiment rice yields, the suspicion of yield declines for irrigated rice-rice and rice-wheat sequences has been dispelled by a competent analysis for thirty sites in nine countries. Yield potential per day for irrigated rice in tropical zones has increased and this must continue to meet the future food requirements.

Encouragingly, for rice, the new plant type for irrigated systems has a yield potential per season in tropical Asia of 12 t/ha - compared to 10 t/ha for the cultivars grown at 1998-2000. In farmers' fields, this increased potential should result in Asian average irrigated-rice yield progressing from 5 to 6 t / ha. By 2010, cultivars shall combine new plant type attributes with those of (indica) hybrid rice, giving a yield potential of 14 t / ha. For rainfed-lowland-rice systems, the new plant type is expected to have a yield potential in tropical regions of 5-6 t / ha.

For livestock in rice-producing countries, annual growth rate shall be double the growth rates for crops. However, rates of increase in animal populations and in meat production shall slacken during 2002-2030. But livestock shall become a larger component within rice-farm enterprises; and maize and oilseed shall feature more strongly in the cropping, although livestock systems shall impose increasing pressures on the environments.

Ricefield fish may in the future be grown and harvested to the same extent as at 2000-2002.

For the rural natural resources, rural population increase shall impose increasing pressures. There are substantial challenges in implementing policies that simultaneously and harmoniously address the goals of poverty reduction, rural growth, and sustainable natural-resource management.

Pesticide applications pose threats to environments and to farm operatives. Promoting IPM and judicious pesticide use may be encouraged through programmes of taxation, training and labelling.

Increased temperature (from climate change) may in sub-tropical ecozones increase the fungal and viral diseases and the insect pests. Fortunately, most insect pests, weeds, and some bacterial, fungal and viral diseases can be managed effectively. For the Indo-Gangetic plains, there shall be adverse consequence for post-rice wheat.

For low-lying coastal ricelands, anthropogenic sea-level rise shall increase salinity and decrease yields. At mid latitudes, decreased precipitation shall have adverse effect on rainfed-rice systems.

For rice-system income and livelihoods, and for eliminating child undernourishment, concerned development agencies suggest three requisite foundations: broad-based economic growth; growth in agricultural

production; and investment in education and health. For rural Asia, they emphasize that "Heavy biases against rural people in acquiring human assets are inefficient as well as unjust, and in most cases are not diminishing" and that "The cost of a rural workplace is substantially less than the cost of an urban workplace."

Fortunately, recent forecasts suggest that by Year 2003 overall economic growth may reach or exceed 5.0 percent per year in most rice-growing countries, which should be helpful in reducing hunger and poverty. Hunger and poverty are each higher in rice-growing countries that depend on non-irrigated rice systems for their food production. Under such settings, off-farm employment and income, and public safety nets are particularly important.

Of global significance, at 1996 there resided within the four most populous rice-producing countries (China, India, Indonesia, and Pakistan) three-fourths of the global total of undernourished persons. By 2015, these four populous countries and their rice systems shall facilitate four-fifths of the global decrease (390 M) in undernourishment.

Rural-urban migration is stimulated by the inability of smallholder farms to generate sufficient income to support a family. Consequences are that rainfed-rice-system peak-period labour is increasingly provided by women, and the proportion of woman-headed households ranges from 20 to 40 percent.

Rural development strategies and opportunities

The livelihoods-oriented strategies here proposed acknowledge that in East and South Asia poverty is predominantly rural. They acknowledge also that rural pro-hungry, pro-poor programmes should be based upon the strengths of resource poor persons, and should use the assets of communities to assist the poor to help themselves escape from poverty, and should help build social capital. They recognize that the rural poor are especially dependent on their labour, and that the generation of rural employment is vital. They recognize also that investment in women is crucial in achieving sustainable development, food security and poverty reduction, and that investment in women can be made within interventions in agricultural production, natural resources management and rural income generation.

Strategies shall be based also on best-practice and success-case experiences. Features that previously lessened Asian hunger and rural poverty included investments in infrastructures and irrigation, education and female literacy, agro-technological research and extension, and institutional reform.

Increases in rice-system production and income shall depend on increases in crop and livestock and food product yields per unit time and land area, and per unit of other natural, human and purchased resources. But for very poor farming households, the priority is not yield - but the lessening of risk.

Irrigated rice systems shall contribute most of the increased food production that shall ensure national food security. However, governments and civil societies now accord priority to non-irrigated rice-lands and new strategies are being adopted in expectation of substantial returns in enhanced livelihoods, production, national wealth, and sustainable resource management, and of lessened poverty per unit investment.

In most ecozones, small farms employ more workers per hectare and achieve higher productivity than larger farms, and their proportionate contribution to food security is increasing. Moreover, confirmed usage of any piece of land is a vital asset wherewith a landless family can escape poverty. Assistance to governments to implement pro-smallholder policies shall thus be a worthwhile intervention. As also shall be assistance to strengthen policies for natural resources, for rural endowments, investments, institutions, and micro-finance, for price supports, subsidies and agricultural trade.

The quantified interaction between agricultural primary production and rural-income generation is highly relevant. A 1.0 percent increase in agricultural output value results in a 0.5 to 1.0 percent increase in the outputs of the associated non-farm sector.

Cultivar development, using both conventional and molecular approaches, geared to high yield potential, improved nutritional quality, increased nutrient use efficiency and greater tolerance to biotic and abiotic stresses must remain a high priority. Priority should be given to bridge the yield gaps. For the irrigated and the favourably rainfed lowlands, the yield-gap methodology can be incorporated within the Rice-Check Package, with its farmer-directed dictum: observe, measure, record, interpret, act. By following this dictum, the farmers generate crucial inputs for their participatory, extensionist-guided regular discussions and evaluations of their

rice management achievements. In all ecozones, rice-seed quality and vigour is crucial: quality seed increases yield by 9-15 percent and produces grain of higher quality and price.

Crop-livestock synergy can be particularly beneficial in smallholder agriculture. It provides opportunities to intensify production, to accumulate assets and to diversify risk. In rice smallholdings, poultry, cattle and pigs are prominent.

For rice, if the benefits from the quality cultivars and seeds are to be maximized, management of water, nutrients and pests must be optimal.

For water and irrigation resources, with many competing demands, there is awareness of the need for near- and long-term strategies and policies. For irrigation, it is recognized that the efficiency of water distribution and use must and can be increased. Many irrigation systems need modernization: economic returns to modernization can be substantial - even where returns to the original investment were low. Increasingly, irrigation-user groups shall operate and maintain the irrigation facilities to promote equity and water savings. Effective management of rainwater is extremely important.

For nutrients management, and for all rice-system crops, there must be increased fertilizer-use efficiency and decreased nutrient losses. There are emergent methodologies and associated diagnostic and decision-support systems - notably for irrigated-rice systems. Similarly, there are established procedures of integrated plant nutrition management for different production regimes.

Riceland nutrients management has implication for the global atmospheric environment. It is acknowledged that agriculture, generally, should focus on lessening nitrogen emissions, but with some attention to carbon emissions and sequestration.

The lessening of riceland emissions of nitrous-oxide and ammonia shall depend on the adoption of environment friendly N-fertilizer procedures. There shall be need for appropriate policies with regulation and enforcement. There is a crucial need to identify and phase out subsidies that reward environmental degradation, and to initiate policies that reward sustainable natural-resource management.

Riceland sequestration of carbon, in soil or in standing crops, is a viable (Agenda 21 and/or Kyoto Protocol) procedure wherewith to counter CO_2-enhanced global warming. Such procedure, with financial compensation, might be particularly attractive to rice farmers operating on constrained or degraded lands.

Post-harvest value-adding activities, at household scale within rice-based communities, also provide opportunities for creation and expansion of employment and for income augmentation.

The endowments and associated services most needed by riceland communities include legally-assigned land, equitable access to irrigation, to agricultural-extension services, and micro-finance, functional institutions, infrastructures and markets, and viable opportunities for rural enterprises. Education, health care, and other social services need strengthening in many rural areas.

Micro-finance is important to rural households; it is often essential for the adoption of new technologies. For the rural poor who lack credit worthiness, systems of safety nets are vital. The need to identify the target clientele is well recognized.

Endowment investment in skills and vocational training shall be worthwhile in preparing current and future farmers and farm-family women for the rice systems of 2010-30. For current rice-system farmers, training shall best be provided through extension programmes, perhaps adopting farmers' field schools and whole-family training. Different strategies shall be needed for the future farmers - who may wish to specialise in a particular commodity, and to use their literacy, numeracy, and computer competence.

Crucial for overall rural development is rural-women's development and education. Education of girls is probably the single most effective investment in development that any country can make. Helpfully, rice-system interventions afford opportunities to educate, to train, and to empower rice-farm women. Women-oriented skills training in seed management, fodder production, and straw livestock-feed management could be highly cost-effective. Training of adult rural women in financial management and farm-family nutrition will prove highly effective.

There is growing commitment that globalization of trade can and must be made to work for the hungry and poor. The WTO's General System of Preferences affords a route whereby developing-world farmers can

increase their market share. Recognizing that trade liberalization shall create gainers and losers, interventions can help prepare the safety nets wherewith to protect and assist the losers.

To implement pro-hungry interventions, appropriate local and national government policies need to be operational. For several rice-growing countries, a priority need is to strengthen the institutional capacity wherewith to define and implement policies and procedures for primary production, for value-adding enterprises and for infrastructural supports.

Policy-oriented interventions can assist governments to review their rural development policies and if appropriate to modify them so as to maximize smallholder activity. Interventions can help identify and amend anti-rural and anti-agricultural and anti-smallholder policies and fiscal regimes. Repeal also of environmentally damaging subsidies and price supports. Pro-actively, interventions might help initiate tax-incentive mechanisms wherewith the private sector can be encouraged to invest in smallholder agriculture. Policies on water resources and use, and on gender mainstreaming must be in place.

Prospective interventions

Progress towards the Year-2015 food-security and poverty alleviation targets has been less than required. Part of the cause is the decline in global assistance to developing-world agriculture during 1989-99. Within that decline, the regional differences (at 1998) among flows of development aid per poor person are revealing: US$950 / person to Middle East and North Africa, US$30 / person to East Asia, and only US$10 / person to South Asia.

Part of the remedy is to increase and sustain investments in physical and human resources for developing-world agriculture - particularly for Asian agriculture. Crucially, investments and interventions must address the vision and goals of providing to the younger generation of hungry and poor persons a realistic expectation that their livelihoods shall be more agreeable than those of their parents.

There is need for investments in irrigated and in non-irrigated ricelands. Interventions in irrigated systems would help produce the increase in food that shall ensure national food security. Interventions in non-irrigated systems would lessen rural poverty, rural-urban migration, and natural resource degradation. In all ecozones, interventions can be guided by existing codes of best practice, with maximal adoption of indigenous knowledge and experience.

The broad objectives for various candidate interventions are characterized as technological, socio-economic, or institutional, policy and infrastructural. Procedurally, and as urged by various stakeholders, the interventions would be integrative among those three types of objectives.

However, integrated development demands attention to education, to health care, to transport, and to micro-finance. The totality of required interventions thus extends beyond the capacities of FAO. Interventions should thus be implemented holistically through a multi-stakeholder, multi-disciplinary coalition. That coalition would expect to include the beneficiary communities, local NGOs and civil-society, faith groups, academia, private-sector companies and finance institutions, agricultural-extension and agricultural-research personnel, national ministries and component agencies, and several UN agencies.

Procedurally, assistance to particular interventions shall be provided only in response to member-states' requests. To facilitate such requests, this publication includes a "menu" for 33 prospective interventions. Among those 33 candidates, 15 are characterized as technological, 6 as socio-economic, and 12 as institutional and infrastructural.

From the menu for prospective interventions, initial choices would be made by member governments, thereby ensuring congruence with their national policies, strategies, and workplans, and with the specific needs of their targeted riceland communities and farm families. The required pro-poor targeting would be accomplished in partnership with national agencies. Agronomic targeting would be achieved through yield-gap analyses, and by considerations of markets and infrastructures and of socio-economic and cultural constraints.

Operationally, interventions would be implemented through a twin-twin-track strategy. In this strategy, the first twin pair would have one "track" for the non-irrigated ricelands, with the second "track" for the irrigated lands. In the second pair, one track would accommodate near-term interventions (2002 - 2006), the second the

medium term (2002-2012). Within the first pairing, interventions in the non-irrigated (less-favoured) lands would expect to increase productivity, employment, and income, and hence help lessen hunger and rural poverty. Interventions in the irrigated lands that accommodate the intensive rice-rice-based and rice-wheat-based systems would help increase national food production and security, while increasing the incomes of smallholder families.

Within this twin-twin-track strategy, interventions are categorized according to applicability to non-irrigated, irrigated, or all rice-based systems, whether directed towards primary productivity, value-adding processing, or sustainable resource management, whether technological, socio-economic, or institutional/ infrastructural, and whether appropriate for near-term or medium-term support and implementation. They are code-referenced to highlight inter-connections among the interventions listed in different categories.

Outputs expected from these interventions would be several. However, many impacts on hunger and livelihood shall be manifest only in the long term. Moreover, many processes and factors beyond these interventions shall strongly influence riceland hunger and wellbeing. Nonetheless, participatory monitoring and evaluation could in the medium term quantify the interventions' impacts on incomes, nutrition, and empowerment, and on productivity of smallholdings and profitability of micro-enterprises.

For communities, districts and countries, trends in wellbeing would thus be monitored through increments in rural investment and infrastructural constructions, through enactments of policy, taxation and regulatory reforms, through the aggregate sales by new micro-enterprises, and through the quantity and quality of human-resource development - in households and in institutions, and particularly for women. At household scale, monitoring of nutrition, hunger, poverty, wellbeing, and aspirations would use procedures of baseline and recurrent sampling. Monitoring of agricultural productivity trends would be accomplished through analyses of factor productivities and through the numbers of adoptions of more-productive cropping/farming systems.

FAO's catalytic and participatory roles within the prospective interventions

FAO, with its experience, expertise and Asia-Pacific presence, would be a major participant in much of this intervention and monitoring. Additionally, FAO would help catalyse the contributions of many partners and stakeholders - including various UN agency stakeholders.

Collaborative action by several UN agencies would permit that interventions could be undertaken within the mandates of the UN Development Group, the UN Development Assistance Framework, and the UN Joint Consultation Group on Policy, and could be accommodated within the multi-UN Agency Administrative Committee on Coordination, and its Network on Rural Development and Food Security.

Following member governments' initial choices among candidate interventions, the chosen interventions would be implemented holistically through multi-stakeholder, multi-agency, multi-disciplinary coalitions. FAO would help convene and service such coalitions. As and where appropriate, interventions and operations could be associated with the national components of the FAO facilitated Special Programme for Food Security (SPFS).

Interventions would be supported also by the personnel and resources within the FAO initiative for Priority Areas for Inter-disciplinary Action (PAIAs). Indeed, some candidate interventions already provide a "test-bed" (in Indonesia) for the evolving methodology whereby PAIAs provide technical and analytic support to SPFS activities.

Operationally, interventions would be implemented within the suggested twin-twin-track strategy. They would operate at village or at irrigation-secondary level, and would there proceed in partnership with individual farmers and with farmer and enterprise groups - especially with women farmer and women entrepreneur groups. They would involve local extension personnel and private sector service providers, and locally active NGOs and community-based organizations (CBOs).

Targeting of prospective beneficiaries would be accomplished by the multi-agency coalitions. FAO would assist such targeting through the Food Insecurity Vulnerability Information and Mapping System. To complement that targeting, locally knowledgeable NGOs and CBOs could help ensure that the interventions utilized the community-specific comparative advantages and strengths.

The menu of candidate interventions shall enable various stakeholders to make an initial appraisal and prospective commitment to specific menu items and to the goals and strategy here proposed. FAO is able and willing to assist member governments in making such appraisal.

This executive summary and main report shall be shared with the many national and international agencies and groups that constitute the stakeholder community for these rice-based livelihood systems. It shall in particular be shared with the several UN agencies that have concern for the alleviation of rural Asia's hunger and poverty - including the International Fund for Agricultural Development and the United Nations Development Programme. It shall be shared also with the Consultative Group for International Agricultural Research, and with bilateral and multilateral sponsors of programmes of rural development and poverty alleviation, and with the regionally-active development banks.

It is pertinent that FAO has expertise and experience in designing institutional mechanisms to facilitate multi-stakeholder initiatives. Additionally, FAO's Medium-Term Plan includes Asia-Pacific-based food-security programmes and a rice-specific support strategy to help enhance the livelihood of smallholder families. The Medium-Term Plan supports governments' Special Programmes for Food Security. That support includes Priority Areas for Inter-disciplinary Actions (PAIAs). FAO similarly has the mandate and expertise to assist member governments to devise and to implement policies that facilitate smallholder enterprise, rural livelihood, and food security. The technical departments of FAO can thus contribute to much of the needed riceland development.

Within its Asia-Pacific programmes, FAO synthesizes components from several PAIAs to create five multi-disciplinary thrusts. These address biotechnology, biosecurity and biodiversity; livestock intensification; world trade and policy environment; disasters preparedness and management; and rice-based livelihood systems and lessening hunger and rural poverty.

Conclusion and epilogue

There are many constraints and challenges to the lessening of rural hunger and poverty, whether generally or within the rice-based livelihood-support systems. Fortunately, there are many technological, social, economic, institutional, and infrastructural opportunities wherewith to address those constraints and challenges. Encouragingly, recent forecasts permit optimism that there shall be increased national resources wherewith to combat rice-system hunger and poverty. Moreover, there is international willingness and commitment to provide external resources to augment those national resources.

Thus, it is hoped that this executive summary (and the main text of this publication) shall engender within a knowledgeable and influential readership a heightened and quantitative awareness of the essential features and importance of these vital Asian rice systems. To strengthen awareness particularly of the economic, social, and environmental significance of the ricelands and of the 3 billion persons who depend upon them for an often substantial part of their daily food. And within that significance, to emphasize that a food-supply system that is so large and so pro-poor as the rice system has the potential to impact - favourably or adversely - on the world's food security and on its politico-economic stability.

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Acronyms and abbreviations

ACC	Administrative Committee on Coordination (UN System)
ADB	Asian Development Bank
AEZ	Agro-ecozone
ann	annum
ASEAN	Association of South-East Asian Nations
B	Billion
BMI	Body-Mass Index
CBO	Community-Based Organization
CGAP	Consultative Group to Assist the Poorest
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Centre)
CSD	Cropping Systems Directorate (India)
d	day
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FARM	Farmers-centred Agricultural Resource Management
FAS	Foreign Agricultural Service (US Department of Agriculture)
FIVIMS	Food Insecurity and Vulnerability Information and Mapping System
GDP	Gross Domestic Product
GIS	Geographic Information System
GMO	Genetically Modified Organism
GNP	Gross National Product
ha	hectare
HYV	High Yielding Variety
IARC	International Agricultural Research Centre
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Centre
IFPRI	International Food Policy Research Institute
ILMT	Integrated Land-Management Technology
ILO	International Labour Organisation
IMF	International Monetary Fund
IPM	Integrated Pest Management
IPNM	Integrated Plant Nutrient Management
IPNS	Integrated Plant Nutrient System
IPR	Intellectual Property Right
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
kcal	kilocalorie
kg/ha.day	kilogramme per hectare per day
LEAD	Livestock, Environment, and Development (Initiative)
Mha	million hectare
Mt/ann	million tonne per annum
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development

PAIA	Priority Area for Interdisciplinary Action (FAO)
pers	person
RAP	Region of Asia and the Pacific (UN System)
SAARC	South Asian Association for Regional Cooperation
SARM	Sustainable Agricultural Resource Management
SPFS	Special Programme for Food Security
TCTTI	Thana-Level Cereal Technology Transfer and Identification Project
TFP	Total Factor Productivity
t/ha	tonne per hectare
UK/DFID	United Kingdom Department for International Development
UNCDF	United Nations Capital Development Fund
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
UNIFEM	United Nations Development Fund for Women
WAICENT	World Agricultural Information Centre
WFP	World Food Programme
WFS	World Food Summit
WHO	World Health Organization
WTO	World Trade Organization

Abbreviations specific to the proposed interventions (Section 5)

T: Technological intervention; E: Economic or social intervention;
I: Institutional or policy or infrastructural intervention.

B: Both non-irrigated and irrigated rice systems; N: Non-irrigated systems; I: Irrigated systems.

C: Crops; L: Livestock; F: Fish; A: Agro-forestry; P: Policy; V: Value-adding;
T: Training, information, and capacity strengthening; S: Sustainable natural-resource use.

2: Identifier number within the preceding codes.

ASIA'S RICE-BASED LIVELIHOOD-SUPPORT SYSTEMS: STRENGTHENING THEIR ROLE IN LESSENING HUNGER AND RURAL POVERTY THROUGH SUSTAINABLE GROWTH IN AGRICULTURAL ENTERPRISES

1. Purpose, background, vision, and goals; FAO's interventions and mission

This document is concerned with the rice-based agricultural systems of Asia. Its *purpose* is to engender within a knowledgeable and influential readership a heightened awareness of the key features, global importance, and pressing needs of these systems in supporting and sustaining human livelihood and food security during the periods 2002 to 2015 to 2030. These periods are those for which informed estimates have been made for the requirements of Asian agriculture in meeting the food-security and livelihood needs of the projected human populations in order to lessen substantially (by those target dates) the numbers of undernourished adults and children and the levels of poverty. Those estimates derive from several sources, including the World Bank, the Asian Development Bank (ADB), the International Fund for Agricultural Development (IFAD), the World Food Summit, the International Food Policy Research Institute (IFPRI), and FAO.

Within these time-frames, the document identifies a *vision* and *goals* (Section 1) and *candidate livelihood-oriented activities* (Section 5) wherewith national organizations could be supported by FAO to initiate key activities in rice-system production and products utilization - for rice, non-rice crops, and livestock - and in institutional supports. Such activities would initiate within the ongoing national programmes - during Years 2002-2006 - and would seek to assist the marginal and smallholder rice-farm families and the associated rural landless families. The document highlights how progress towards the Year-2015 food-security and poverty-alleviation targets has been less than required, and suggests that this disappointing progress is in part the result of the substantial decline in global assistance to developing-world agriculture during 1989-99.

However, the document recognizes and emphasizes that increased agricultural production - though a *necessary* condition - is not of itself a *sufficient* condition for lessening rural poverty, under-nutrition, and rural-urban migration, nor for creating rural employment and strengthening rural livelihoods. These livelihoods depend not on food supply alone, but on complex interactions of social, economic, and natural-resource endowments. Multi-stakeholder multi-agency partnerships of wide range are thus needed to create and supply the support that can help lessen poverty among rice-system smallholder families and correspondingly lessen food insecurity in both rural and urban areas.

For food security, there are responsible forecasts for the increasing requirements for rice during 2003-2030, and responsible expectations that widespread adoption of current and emerging best-practice production procedures can meet those requirements, and can do so with a diminishing demand on biophysical and human resources. The resources thus freed from rice production shall allow diversification of rice-based farming systems and of income-generating employment-creating enterprises.

Other extensive food-and-livelihoods systems in East and South Asia are the *upland* and the *highland* mixed farming systems. They, like rice systems, are home to many poor persons, and contribute to those persons' food security. Appropriate programmes are needed for these upland systems. However, and without gainsaying the needs of other Asian farming systems, this document addresses *only* the rice-based farming systems, with their rice and non-rice crops, their livestock and fish, and their value-adding employment-creating enterprises, and their unique submerged-soil ecological regimes, biodiversity, and environmental challenges.

The rice-based systems do, fortunately, constitute an effective and resilient vehicle wherewith to deliver the wide-range support needed to help lessen national food insecurity and rural poverty. Such supportive programmes would expect to involve public- and private-sector and international agencies, working in partnership with components of civil society and with the rice-system families. FAO's prospective contributions within those programmes would be consistent with its Medium-Term Plan 2002-2007 (FAO 2000a) and with the FAO-assisted Special Programme for Food Security. Those contri-butions would, in particular, be provided within that Medium-Term Plan's initiative for Priority Areas for Inter-disciplinary Action, with their intended value-adding benefit from multi-disciplinarity.

1.1 Rice systems and the lessening of poverty and undernourishment

1.1.1 The rice systems

In several respects, the geographic *aggregation and contiguity* of the many Asian rice-based farm systems is globally unique. During 5 000 years, the particular feature of bunded, terraced ricefields has allowed a *sustainable* use of land and of monsoonal rainfall, often of high-intensity. That sustainable usage has come under man-made threat only during the last three decades. Moreover, within those bunded fields, rice cultivars are well adapted to benefit appreciably from the particular soil-chemical regimes that result from prolonged soil submergence.

Similarly, the submerged-soil ecosystem provides a habitat for various indigenous and introduced aquatic species which have economic and nutritive value - particularly to the poorest riceland dwellers - and which contribute to rice-system biodiversity. At the river-basin scale, the aggregations of bunded ricefields provide highly-effective flood-regulatory mechanisms; the cost of replacing such mechanisms by steel and concrete would dwarf national budgets.

These contiguous Asian ricelands extend from Japan and the Solomon Islands in the east to Pakistan and Iran in the west. They are thus within the Asia and Pacific Region of the FAO/UN System - a Region which produces and consumes about 90 percent of the world's rice, and that is home to many extremely poor persons among a population that constitutes 53 percent of the global total. Seventeen Asian countries annually harvest at least 0.6 Mha of rice. They have an aggregate population of 3.2 billion persons; they comprise: Bangladesh, Cambodia, China, India, Indonesia, Iran, DPRKorea, RoKorea, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, and Viet Nam. Eleven of them are classified as *Low-Income Food-Deficit*. Twelve of them fall within the two most-severe categories of *prevalence-plus-depth of hunger*.

The ricelands feature strongly in five of the FAO-delineated agro-ecozones. They feature also in the East-Asian and South-Asian sections in a recent compilation (Dixon *et al* 2001) of a poverty-interventions-oriented categorization and mapping of the world's major "generic" farming systems.

The ricelands' farming systems - of crops and livestock - have in all major rice-growing countries generated, and continue to sustain, the *agricultural infrastructures* and the many associated on-farm, off-farm, and non-farm *value-adding rural enterprises and services*. Indeed, Asian agriculture - including rice-based agriculture - provides much of the raw material needed by (predominantly urban) manufacturing industry. Thus, poor harvests, from whatever cause, can and do impact adversely on nations' commerce, trade, and total economies.

Though some rice systems are practised outwith the contiguous Asian rice-growing belt, their magni-tudes - whether of area, production, or economic value - are insubstantial in comparison with the Asian totals. Moreover, for several countries within the contiguous belt, rice has a cultural and also, though now diminishing, a political dimension. Thus, there are appreciable numbers of rice festivals and rituals. In some dialects, a good-morning greeting translates as "have you eaten rice today?" The issue of rice price is often-times crucial in influencing large urban constituencies during demo-cratic elections. Correspondingly, the issue of rice importation - particularly at local rice-harvest time - is of vital concern to smallholder rice producers. Presidents of populous nations deem it appropriate to participate in "national rice weeks"; and the UN System justifiably discusses whether Year 2003 might be designated as "World Rice Year".

The Asian ricelands support almost *3 billion rice consumers: one-half of the world's population, and more than one-half of its hungry*. The intensity of that nutritional support is often very considerable (FAO 2000e, and Table 8 following). It is therefore highly pertinent that responsible estimates, which accommodate likely changes in population, incomes, diets, and the proportion of hungry (FAO 2000d), suggest that the global developing-country demand for rice (predominantly in Asia) shall progress as approximately 540, 665, and 765 Mt / ann (million tonnes per annum) at 1995/97, at 2015, and at 2030.

Asia's ricelands and their supportive rice-buffer stocks thus have a year-on-year and increasing requirement to supply about 600 Mt rice / annum. If during a succession of years the supply should be inadequate, and with a rest-of-the-world rice production of only 60 Mt / ann, then the task of substituting any substantial shortfall by alternative, consumer-acceptable-and-affordable foods shall be immense. The economic and political consequences - in an increasingly globalized world - might be similarly immense. Indeed, *global* food security

is to large extent determined by the *rice security* of Asia, and by the products of its rice-based systems. *A system that is so large and so pro-poor as the rice system has major potential to impact - favourably or adversely - on the world's food security and on its politico-economic stability.*

Section 3.5.6 following correspondingly quantifies some of the *global* impacts of the 1997-99 economic crises in South-East and in North-East Asia. To prevent such future rice shortage and adverse consequences, the remedy, frequently stated in this document, is that the *necessary investments* in physical and in human resources - which declined drastically during the 1990s - must be substantially increased and sustained.

In aggregate (FAO 2000b), the Asian ricelands - whether "rainfed" (i.e. non-irrigated) or irrigated - have an annual harvest area of *» 135 million hectares* (Mha). They are tended by perhaps 200-300 million persons, both landed and landless, full-time and part-time. They support about 200 million bovine livestock, and rather fewer small ruminants. They receive (IRRI 1997, FAO 2000d) about one-fifth of the global total of *manufactured fertilizer nitrogen.*

After the monsoon-season rice harvest, some of the riceland may be occupied by a second and possibly a third rice crop during one farming year. For all Asia, FAO (2000c) indicates that rice-rice and rice-rice-rice sequences may in aggregate occupy 28 Mha of riceland. This document suggests that the rice-wheat and rice-rice-wheat sequences may together occupy another 25 Mha of riceland.

The Asian rice systems have since 1960 helped achieve *impressive growth rates* in agricultural production. Thus, during 1970-2000 and for all developing Asia, all-cereals production almost doubled, whereas harvest area increased (ADB 2001a) by a mere 4 percent. Moreover, during the decades 1960-2000, unit (real-term) costs of rice production decreased by 30 percent, while rice prices decreased by 40 percent (IRRI 2001a).

A similar *global* long-term decline 1965-1995 in the real price of food is reported by FAO (2000d): while average grain yield increased from 1.4 to 2.8 t/ha (all grains) and cropping intensity increased x 1.1, such that the land required per unit of food production decreased by 55 percent, the arable land per person decreased by only 42 percent.

Notwithstanding that each individual farm and its household and its farming system is unique, Dixon *et al* (2001) were able to identify and map - for the developing world - a set of eight "generic" farming systems derived through a grouping of 72 farming systems that are widely practised throughout one or more of FAO's development regions. Within each "generic" system, there is sufficient commonality, both of agronomic and of socio-economic conditions, that system-wide strategies for livelihoods-enhancing interventions can be formulated.

Two of those development regions - East Asia and South Asia - and two of the generic systems - *rice-rice-based* and *rice-wheat-based* - are expectedly prominent among the Asian farming systems. All eight generic systems are characterized in terms of their resource potential and by their current level of agricultural intensification and degree of access to services. For each of them, Dixon *et al* indicate the extent to which each of five *candidate strategies* is likely to lessen rural hunger and poverty.

Those five strategies comprise: intensification of existing production patterns; diversification of production and processing; expanded herd or farm size; increased off-farm and non-farm income; and exit from agriculture in the particular farming system. The five strategies are not mutually exclusive: intensification of present (perhaps staple-food) production can and does release land and human resources to facilitate farming-system diversification and hence a more-balanced diet or/and increased income and a strengthened livelihood.

The "generic" Asian ricelands, which include lands adjacent to and associated with the rice-rice and rice-wheat fields, are managed and cultivated by some *130 million rice-farm households* - nearly two-fifths of the global total of farming households. The members of those households thus constitute no less than *one-ninth* of the world's population. About 80 million of the rice-farm households are in South Asia; their aggregate population represents *one-fifteenth* of the world's total - and a considerably higher proportion of the world's poor (Dixon *et al* 2001).

The rice-based farming systems are with minimal exceptions *rurally* located. *Rural* is generally defined as pertaining to communities comprising fewer than 5 000 inhabitants (ADB 2001b, IFAD 2001 - though different criteria may be used by other agencies). Additionally, the term *rural* implies certain characteristics of political organization, age profile, employment prospects, and access to natural resources (ADB 2001b).

1.1.2 Undernourishment and poverty

In Asia, the rice systems undoubtedly contributed to the lessening of rural and urban hunger and poverty, and to the sustaining of livelihoods. Thus, the number of *adequately-nourished persons* (*via* Table 1 following, East Asia and South Asia, and rural and urban, combined) increased from 1.12 B (billion) in 1970 to 2.56 B in 1996. *Incomes* - as GDP / person, rural and urban combined - almost doubled during 1970-2000 (ADB 2001a). Correspondingly, the number of *non-poor persons* (East Asia and South Asia, rural and urban, combined) increased from 1.80 B in 1970 to 2.37 B in 1998.

Relatedly, IFAD (2001) reports that as food-staples' yields increased during the 1970s and 1980s, there was a substantial decrease in poverty incidence. IFAD was thus able to affirm that the wheat- and rice-led Green Revolution during 1960-1990 did indeed manifest an excellent anti-poverty record. IFAD correspondingly *cautioned* that as the rate of staples-yield-increase slackened during the 1990s, so also did the rate of decline in the numbers of poor. There is thereby implication that future increases in the yield and production of the poor persons' staples - including rice - are likely to help lessen poverty, and correspondingly to enhance rural livelihoods.

It is thus pertinent to note the strong similarity in the current (1998-2000) global productions of the three dominant food-security cereals - rice, wheat, and maize - each 580 - 610 Mt / ann. It is noteworthy also that among those three crops, the proportion that is used for poor persons' food is much the highest for rice. And noteworthy that within the Asia-Pacific rice-producing region, their totals are 530 Mt/ann for rice (nine-tenths of the global rice total), 210 Mt/ann (plus 30 Mt/ann imports) for wheat, and 150 Mt / ann for maize (mostly for livestock feed). Relatedly, and excepting richer rice-growing countries and China, livestock products contribute less than one-tenth of dietary-energy requirements. *Thus, in dietary terms, as also in social, economic, and ecological terms, the contributions of non-rice crops and of livestock are in the major rice-growing countries dwarfed by those of rice.*

However, despite the impressive post-1960 achievements in staples yields, and because of the geographic patterns of agricultural growth and the inequity in access to food caused by lack of purchasing power and/or inefficient distribution of the available food, *hunger and poverty still persist* in various Asian countries (IFPRI 1999a, UNICEF 2000, FAO 1999a). This concern for continuing hunger - and the reaffirmation of global commitments and of actions to eradicate this hunger - shall be the focus of the June-2002 World Food Summit.

It is thus noteworthy (FAO 1998a, IRRI 2001a, Dixon *et al* 2001, IFAD 2001, ADB 2001a, World Bank 2001a) that for Asia's rural families, 40 percent of their gainful employment, and 30 percent of their household income - and as much as 40 percent of income in China, and 50 percent in the poorer rice-wheat-farming households of India - derives from *non-farm* and *off-farm activities*. Such activities include small-scale trading and service, within-household manufacture, and possibly packaging and transport.

This rural non-farm component is growing faster than the off-farm component (IFAD 2001) and is particularly important for rural women (ADB 2001a). Dixon *et al* 2001 suggest that in East Asia and in South Asia it shall be access to non-farm income that shall facilitate a substantial part of the poverty reduction that shall be achieved during 2002-2030. Access to non-farm employment and income is especially important in the non-irrigated rice ecosystems - specifically in the lowland areas with unfavourable rainfall regimes, in the (deepwater) floodprone / swampland areas, and in the rice-growing uplands.

Under-nourishment is defined (FAO 2000d) as an insufficiency of calories for basic energy requirements. *Under-nutrition* comprises both an insufficiency of calories together with an inability, because of health or sanitation constraints, to use maximally those calories that are consumed. In addition to providing calories *via* consumer-preferred foods, an appropriate diet must also supply a sufficiency of vitamins and trace elements - especially vitamin-A, and iodine, iron, and zinc. There is requirement also that families must have sufficient fuel wherewith to cook the available food. Diets may be strengthened also by combining commonly-available foods in such manner as to exploit beneficial enzyme-mediated synergies.

The persons *most vulnerable* to undernourishment include (FAO 1999a) rural landless families and the families headed by poor rural women, and within those families particularly the children (infant, pre-school, and adolescent), pregnant and lactating women, the aged, the disabled, and orphans. These poor persons - and

poor people generally - depend (IFAD 2001) on low-cost staples for much of their nourishment and also for their farm-derived income.

Undernourishment, and particularly protein-energy undernourishment, in *children* results in increased infant and pre-age-five mortality. Moreover, the survivors suffer impairment of learning ability in addition to limitations (including "stunting" and "wasting") on physical/ biological growth and on life expectancy. The undernourished children are thus less productive and more illness / disability-prone as adults, and the consequential global costs are immense (IFPRI 2000a). Indeed, ADB (2001b) affirms that the proportion of children undernourished is a key indicator of the *quality of life* of a whole rural community.

Juvenile undernourishment is quantified in terms of physical-growth characteristics: weight and height and "stunting" and "wasting" and "body-mass index" at specific ages during 0-5 years, and assessed in relation to USA-derived norms for means and variances. Experience from China (FAO 1998b) indicates that the prevalence of low weight and stunting is less where incomes are higher, parents are more-educated, and there is general awareness of human nutrition and diet.

Women are more likely to be undernourished than men. In part this may reflect the distribution of food resources within households, which may recognize that a labouring man constitutes human capital that must be adequately maintained. And in part it may indicate that women's specific and well-established dietary requirements for vitamins and micro-nutrients, particularly during pregnancy and breast-feeding, are neither widely understood nor appropriately accommodated within rural communities (FAO 1999a).

Thus, for Bangladesh at 1995, FAO (1998b) reports that 58 percent of pregnant women were anaemic; for India, Singh (2001a) records 82 percent of pregnant women, and 74 percent of pre-school children, as anaemic. South Asia in aggregate is home to about one-half of the world's anaemic women (Singh 2001b, quoting WHO). In China, about one-fourth of the population is Vitamin-A deficient (FAO 1998b). Iodine deficiency is prevalent in almost all Asian rice-growing countries: fortunately it is controllable - and is indeed controlled - by iodized salt.

Nonetheless, economic losses to micro-nutritional deficiencies are immense: estimated as US$ 5 B / ann for South Asia alone (Singh 2001b, quoting IFPRI). Moreover, chronic female undernourishment during childhood and/or adolescence results in women of low body-mass index (BMI). Almost invariably, the children of such women also have low BMI - and the situation is perpetuated.

The causes of juvenile and female undernourishment (IFPRI 2000a, IFAD 2001, ADB 2001b) include local *food insecurity, social and economic inequity, and poverty,* together implying a lack of purchasing power wherewith to buy available food, inadequate social and health care for mothers and children, and inadequate water and sanitation.

The most-effective means to combat this undernourishment are to achieve substantial growth in National Gross Domestic Product (GDP), and - demonstratively more effective (IFPRI 2000a) than increase in food supply - to *educate rural females,* both girls and women.

Poverty - as represented by the numbers of persons having less than US$ 1.0 per day (at 1993 purchasing prices) for food, shelter, and other essential needs - currently affects about 1.3 B (billion) persons globally (IFPRI 1995a, UNICEF 2000). Of those 1.3 B persons - of whom about 0.7 B are children and 0.9 B are female (adults or children) - most are undernourished.

In *East Asia and the Pacific* there were (UK/DFID 2000, ADB 2000a, each quoting World Bank World Development Indicators 2000) at 1990 about 0.45 B *poor persons* (28 percent of the total population) and at 1998 about 0.28 B (15 percent). Corresponding figures for *South Asia* were 0.50 B (44 percent of total) and 0.52 B (40 percent).

The positive converses to these preceding statistics are that the numbers and proportions of *non-poor* at 1990 and at 1998 were for East Asia 1.16 B (72 percent of total) and 1.59 B (85 percent), and for South Asia 0.64 B (56 percent of total) and 0.78 B (60 percent). Nonetheless, a continuing total of about 0.8 billion poor Asian persons is unacceptable.

[However, as cautioned by ADB (2000a) and by IFAD (2001 Boxes 2.4 and 2.5), poverty is variously defined and quantified. It may be defined (ADB 2000a, 2001b Box 2) as "a deprivation of essential assets and opportunities to

which every human is entitled". Some definitions include a gender-empowerment aspect. Measurements and enumerations by ***international*** *agencies often adopt the afore-mentioned US$1.0 per day criterion. IFAD (2001 Box 2.4) summarizes the methodologies for quantifying "consumption poverty".*

Some ***national*** *agencies, and for various valid reasons, use - and from time-to-time revise - their own poverty-assessment criteria. There may thus result very divergent values for the numbers of poor persons as reported by national and by international agencies: at 1997/98, the World-Bank estimate (quoted in ADB 2000a Appendix 1) for China was 225 M (million) - compared to the national statistic of 75 M; with a similar contrast (450 M versus 350 M) for India.]*

Nonetheless, enumerations clearly indicate that in most developing countries poverty is predominantly a *rural* phenomenon - thus affecting communities with fewer than 5000 inhabitants. Illustratively, for the rural uplands of northern Viet Nam, IFPRI (2000b) reports a Year-2000 income of only US$ 0.21 / person.day. Generally, and in several Asian countries, the rural poor comprise more than three-fourths of the national total of poor persons; and of those poor, two-thirds (ADB 2000a Box 1) are women.

Importantly, both IFAD (2001) and Dixon et al (2001) emphasize that "the poor" do not necessarily comprise the same persons year-on-year. IFAD (2001) thus urges that distinctions be made between the differing circumstances and needs of the *chronically poor* and the *transitory poor.* For the latter - who may move into and out of poverty in different years and seasons - the provision of insurance and of safety nets can be very helpful.

Goals and targets for the reduction of poverty (rural and urban) throughout Asia were set (and are reproduced in Appendix 2 of ADB 2000a) by the Economic and Social Commission for Asia and the Pacific within its *Manila Declaration*.

1.1.3 Interventions and resources

Singh (2001b, citing various sources), expresses concern that during 1998-2000 interventions and progress towards the various Year-2015 targets *(Manila Declaration, World Food Summit, others)* for lessening rural undernourishment and poverty have been worryingly less than required.

Causes perhaps include (Singh 2001b Table 27, quoting IMF 2000 and FAO's Year-2001 analysis *Mobilizing Resources to Fight Hunger*) a general substantial decline in global assistance - including Development-Bank assistance - to all components of developing-world agriculture during the decade 1987/89 to 1997/99. In South Asia, this decline has been compounded by a rate of government expenditure per agricultural worker that is extremely low (below Sub-Saharan Africa) and decreasing.

This substantial decline has caused anxiety among the international development banks. Thus, ADB (2001b) reports that its loans to support development of agriculture and natural resources, expressed as a proportion of all loans, peaked in the 1980s at 34 percent, thereafter declined to 9 percent at 1997-99, with a slight recovery to 10 percent at 2000; ADB (2001a Appendix 2) describes the decline as *alarming.*

Similarly, the World Bank (2001a) describes the decline in its lending for agriculture (from 18 percent to 12 percent to 9 percent of total lending during 1990-1995-1999) as *precipitous.* IFAD (2001) calculates that the absolute value of global aid to agriculture fell by two-thirds during 1987-98.

Among previous *interventions* that have helped lessen rural poverty, Datt and Ravallion (1995, quoted in FAO 1998b Box C) determined that in India in the early 1990s poverty reduction was facilitated by irrigation, female literacy, and low infant mortality. More recently, (and again for India), the two most-effective poverty-alleviation interventions (IFPRI/World-Bank, Table 20 in Singh 2001a) have been the construction of roads and the sponsoring of agricultural research and development. The next-most-effective have been education and general rural development. Expenditures on irrigation, soil and water, health, and electrification had surprisingly little impact on poverty, though they may have generated other benefits.

For Bangladesh (ADB 2000a Box 4), strengthening human capital had the largest impact on poverty. Investments in physical infrastructure - notably roads and electricity, and in agrotechno-logical research and extension had the next-largest impacts. High potential was recognized for synergies among agriculture, infrastructure, and micro-finance.

Contrarily, in intensely-poor parts of India, Malaysia, and the Philippines, early-1990s programmes of integrated rural development had minimal success in alleviating long-term poverty. But programmes of rural-poor employment - on labour-intensive infrastructure constructions - have since the 1970s lessened rural poverty in Indonesia and in other rice-growing countries (FAO 1998b).

Revealingly, Ravallion and Datt (1996, quoted in FAO 1998b Box C) established that for India growth in the rural economy lessened poverty in *both* rural *and* urban areas; conversely, growth in the urban economy did *not* lessen poverty in rural areas.

Latterly, and recognizing that the *strengths* of resource-poor families and the *assets* of communities differ fundamentally from those of resource-rich communities, various agencies commend that pro-hungry and pro-poor programmes should be based upon the strengths, as distinct from the needs, of resource-poor persons.

IFAD (2001) emphasizes the merits of creating multi-stakeholder partnerships, and presents in its Table 6.4 a typology of pro-poor partnerships of various scales and objectives. IFAD urges that such partnerships must seek to use the assets of communities to *assist the poor to help themselves escape from poverty.* It correspondingly cautions that such partnerships may expect opposition from the non-poor and from "state and local elites", and may thereby expect difficulty in forging "a coalition of the rural poor". Thus, there may often be necessity that the non-poor be included in the partnerships to counter their obstructiveness.

In building on the strengths of rural families and communities, (UK/DFID 2001) urges that develop-ment programmes should focus on the generation of sustainable livelihoods: "the building of social capital should come before the building of roads".

Similarly, ADB (1998) - following pioneering approaches by the Nordic Countries and the World Bank - emphasizes that *investment in women is crucial to achieving sustainable development* and hence to achieving food security and poverty reduction. The developmental benefits derive from general economic growth that results in large part from a healthier, better-educated workforce that constitutes a sound human-resource foundation. Moreover, in very poor households, females often contribute more than males to the household income.

Investments in women can be and indeed are made within interventions addressing issues in agricultural production, natural-resources management, rural-income generation, and rural micro-finance-services provision. However, Dixon *et al* (2001) report (from analyses in the late 1980s) that in some countries women farmers suffer legal hindrance in access to micro-finance and to other entitlements, and that as few as 7 percent of female farmers received any agricultural-extension support, and that only 11 percent of extensionists were female.

Thus, the sponsoring of training - assisted by professional "group facilitators" - for female agricultural extensionists may be cited as a worthy investment component within a rural-livelihood investment programme. There is need for caution, and institutional adjustment, however, since there is anecdotal evidence that in many societies the current female extensionists encounter professional gender biases comparable to those endured in the households by their rural sisters.

It is nonetheless increasingly accepted that the 1980s concept that "women need development" is in this new century firmly supplanted by the recognition that *"development needs women"*, and, moreover, that women should be empowered to influence the agenda for that development. Such empowerment - and appreciable income gain - has seemingly been accomplished (IFAD 2001 Box 6.9) in India by the Self-Employed Women's Association and by the Co-operative Development Foundation.

The agenda for development shall need to be mindful of the statistics and projections (Table 1) for the percentage and totals of *undernourished persons* in East Asia and in South Asia at various dates; the data are for developing countries only, and for adults and children combined, and for rural and urban combined. The 1995/97 total (East + South Asia) of 524 M persons is almost two-thirds of the 791 M *global* total of undernourished persons. Conversely, the number of *adequately-nourished* persons at 1995/97 (East + South Asia) was no fewer than 2560 millions: 83 percent of the total East+South-Asia population. Nonetheless, a total of 524M undernourished persons is *intolerably high*.

An association between undernourishment and poverty is, expectedly, evident in the statistics: for East Asia 13 percent undernourished and 15 percent poor; and for South Asia 23 percent undernourished and 40 percent

poor. Correspondingly, in both sub-regions, the *very poor* are highly likely to be the *most-severely undernourished.*

Table 1: Under-nourishment (percentage and million persons) for East and South Asia: 1970-2030

Location **Date**	**1969/71**	**1995/97**	**2015**	**2030**
East Asia	43 % (504 M)	13 % (240 M)	7 % (144M)	4 % (86M)
South Asia	37 % (267 M)	23 % (284 M)	10 % (165 M)	4 % (82M)

[Source: FAO 2000d.]

Of the 1995/97 global total of 791 M undernourished persons, 167 M were *pre-school children,* of whom in East Asia (including South-East Asia) there were 38 M (23 percent of all East-Asian pre-school children), and in South Asia 86 M (49 percent). These numbers are *distressingly large.* Conversely, the corresponding totals and proportions of *adequately-nourished* pre-school children at 1995/97 were for East Asia 172 M (77 percent of all pre-school children) and for South Asia 90 M (51 percent). Forecasts for the numbers of *undernourished* children at Year 2020 are for East Asia 24 M (of whom 16 M in South-East Asia) and for South Asia 64 M (45 M in India).
[Note: for comparison of statistics and projections, and *for discussion of proposed programmes - the Asian rice systems are generally located within the geographic areas serviced by the World Bank Regional Divisions for East Asia and Pacific and for South Asia. Additionally, in Table 1 and elsewhere in this text, East Asia includes groups of countries that are in some FAO/RAP compilations grouped as South-East Asia, and as Central and North Asia.]*

Encouragingly (and as reflected in the progressions in the data of Table 1), most Asian countries now have per person *calorie intake* exceeding the *food-security* threshold of 2 300 kcal / day. Worrisome exceptions are Bangladesh, Cambodia, Laos and Nepal, each historically low, and DPRKorea - previously having higher calories intake, but recently declined.

Infant mortality rates (UNICEF 2000) for the four first-listed countries are correspondingly high: 60-90 deaths per 1 000 live births, compared to only 5-20 for Malaysia, RoKorea and Sri Lanka, and compared to the Manila-Declaration under-five mortality target of 45.

1.1.4 Rural-urban contrasts and migration – woman-headed households

Poverty is predominantly a rural phenomenon. IFAD (2001) and ADB (2001a Chapter II Box 1) and Dixon *et al* (2001) correspondingly describe how the assets, entitlements and quality of life of rural dwellers are generally inferior to those of urban dwellers, and are becoming increasingly more so.

Thus, rural children and particularly female children are likely to have less and lower-quality schooling than their rural counterparts. Rural health services, transport, communications, and other entitlements and services are more difficult and/or expensive to provide and maintain in rural (as compared to urban) areas, and are consequently of lower standard.

IFAD (2001 Chapter 7) summarizes: *"The heavy biases against rural people in acquiring human assets - especially education and health - are inefficient as well as unjust, and in most cases are not diminishing."*

The global *human population* at Year 2000 is about 6.0 B persons, of whom roughly *1 B are adolescents*. The global total is projected to increase during 2000-2015 by about 75 million persons per year, resulting in a Year-2015 total of 7.2 B - of whom 2.1 B in East Asia (two-thirds thereof in China) and 1.7 B in South Asia (three-fourths in India). For most Asian developing countries, populations in 2015 shall be about 30 percent higher than in 2000. Thus, at Year 2010 the global *urban* population shall exceed the rural population.

Rurally-based agriculture, including fisheries and forests, shall nonetheless be required to meet the food and sustenance needs of both the rural and urban populations; there shall be corresponding need for strengthened facilities for transporting, storing, and marketing these increased food supplies.

Moreover, those urban-dweller food needs are likely to include a higher proportion (as compared to today) of horticultural and livestock products and of edible oils. It is noteworthy (Steinfeld *et al* 1997) that urban dwellers currently consume more livestock products per person than do rural dwellers.

Of the 75 M person / ann global population increase, 60 M shall be *urban* dwellers - many of whom shall by migration have transformed themselves from *rural poor* to *urban destitute*. Hopefully, and as expressed in FAO (2001a), the more successful among the rural-urban migrants may remit sufficient resources to their home villages to ensure the continued productivity and profitability of the family-based farm enterprises.

Correspondingly, the 15 M person / ann global *rural*-population increase shall impose increasing pressures on the rural environments and natural resources (Dixon *et al* 2001, IFAD 2001). Thus, as ADB (2001a) well expresses: *"There are substantial challenges in implementing policies that simultaneously and harmoniously address the goals of poverty reduction, rural growth, and sustainable natural-resource management"*. Such policies shall require also to create rural employment for that portion of the rural-population increment that cannot be absorbed by the on-farm economy.

As observed by ADB (2000a) and by FAO (2000c: Facon, and Zhu re China), a major stimulus to rural-urban migration is the (current) inability of smallholder rice farms and associated enterprises to generate sufficient output and income to support a complete family. Dixon *et al* (2001) suggest that the progressive *decrease* in developing-world average farm size roughly counteracts the progressive *increase* in production per unit area of farm-land, such that farm-derived farm-household income is essentially stagnant. There is also rural-dweller awareness that labourer wages (when obtainable) are higher in conurbations than in villages. Some consequences of the rural-urban migration are that rainfed-rice-system peak-period labour is increasingly provided by women and female children (IRRI-IFAD 2000), and that among the various countries and regions of Asia and the Pacific, the proportion (ADB 2000a Box 1) of woman-headed households ranges from 20 to 40 percent.

The importance of growth in a *national* economy in bringing women into the workforce, and in enhancing their status and wellbeing, and in reducing poverty and undernourishment and population growth is evidenced by ADB (2000a) and IFAD (2001) analyses for *East Asia:* during recent decades, increased demand for labour (agricultural and non-agricultural) raised productivity and wages, and expanded public revenues and thus permitted increased allocations to education, healthcare, and infrastructures. The effects on the numbers of undernourished persons are apparent in Table 1.

For eliminating *child* undernourishment, in developing-Asia generally, ADB (2001a) suggests that the three requisite foundations are: *Broad-based economic growth; Growth in agricultural pro-duction; and Investment in education and health"*.

The Table-1 forecasts for undernourishment - adults and children (FAO 2000d, IFAD 2001, ADB 2001b, IFPRI 1995a) thus derive from combinations of demographic projections with projections for overall and for agricultural economic growth, and for changes in diet and in social, educational, and political circumstances. Complementary forecasts for *South Asia* (IFPRI 1998a) indicate that with an overall *economic growth* of *5.5 % / ann* during 2002-2020 there shall be 66 M undernourished *children* in South Asia at Year 2020 if current policies and programmes are sustained but not expanded. However, if South-Asian economic growth attains only *4.0 % / ann*, then the number of undernourished children would be unlikely to decrease from 86 M (the current total); there would be corresponding consequences for the numbers of rural poor. Encouragingly, recent forecasts (Table 15, citing ADB 2002) suggest that by Year 2003 *overall* economic growth rate may in all South-Asian rice-growing countries reach or exceed 5.0 % / ann.

However, the growth rate (2002-2010) for South Asian *agriculture* was forecast (IFPRI 1998a) to attain only *3 % / ann* (lagging behind that of the overall economy). This 3 percent rate is appreciably less than the *5 % / ann* increase in poor-persons' income that is estimated to be required to enable such persons to "cross the poverty line" by Year 2010. There shall thus be need for *off-farm employment and income,* including non-agricultural employment and income, and probably for public safety nets, if South-Asian rates of rural poverty and undernourishment are to be substantially lessened.

In this context, it is emphasized (IFAD 2001) *"that transferring resources and assets from urban to rural dwellers, and from rich persons to the rural poor, often advances general economic growth"*. Similarly, (FAO 2000f) stresses that the *cost of a rural workplace is substantially less than the cost of an urban workplace* - though ADB (2001b) cautions that urban enterprises will not relocate to rural sites if infrastructures are there inadequate.

Table 2: Child undernourishment (1995-98) as influenced by agro-ecozones in East and South Asia

Geo-Graphic zone	Agro-ecozone	Specification	Total area (Mha)	Main location(s)	Under-nourished (%)
East Asia	AEZ 2	Warm Sub-humid Tropics	14	Myanmar; Thailand.	39 ; 19
East Asia	AEZ 3	Warm Humid Tropics	23	Camb; Indon; Laos; Phils ; Viet.	28 - 52
East Asia	AEZ 5	Warm Semi-arid Sub-tropics	2	NE China	16
East Asia	AEZ 6	Warm Sub-humid Sub-tropics	15	C & SW China; DPRK.	16 ; 60
East Asia	AEZ 7	Warm/cool Humid Tropics	18	S & SE China; Taiwan.	16
South Asia	AEZ 1	Warm Semi-arid Tropics	10	S India.	53
South Asia	AEZ 2	Warm Sub-humid Tropics	24	E India.	52
South Asia	AEZ 3	Warm Humid Tropics	11	Bdsh; India; Sri Lanka.	56; 53; 34
South Asia	AEZ 5	Warm Semi-arid Sub-tropics	2	W India; Pakistan.	45 ; 38
South Asia	AEZ 6	Warm Sub-humid Sub-tropics	9	NW India; Nepal.	53 ; 47

[Sources: AEZs from FAO; rice-specific aspects from IRRI (1997); and child-nutrition data from UNICEF (2000).]

1.1.5 Social and agroclimatic influences

Undernourishment is perhaps more influenced by economic and social factors than by climate-defined *agro-ecozones*. Table 2 lists child undernourishment for three of the dominant rice-system agro-ecozones: FAO AEZs 2, 3, and 6. (These three AEZs, together with AEZs 1, 5, 7, and 8, are usefully mapped in Figure 1 of IRRI 1997.) Table 2 thus indicates, for pre-school children, relatively slight dependence (*within* South Asia, or *within* East Asia) on AEZ, but a *substantial* dependence (South *versus* East Asia, and *among* East-Asian countries) on geographic location, and probably on economic/social factors.

IFPRI (1995b) hypothesizes that the more fertile lands (agro-ecozones) attracted the highest population densities, and the consequential pressure on the ecozone resources results in substantial undernourishment. Moreover, this high population pressure may interact with ecozone-related diseases (human trypanosomiasis and malaria) to increase further the incidence of under-nutrition.

Additionally, as shall be indicated in this document's chapter 2.1.2, rice systems are usefully characterized in terms of their water regime - whether irrigated, rainfed lowland, rainfed flood-prone / swampland, or rainfed upland. Analyses in chapter 3.1.1 suggest that among rice-growing countries both the *intensity of hunger,* and the prevalence of *poverty,* are higher in countries that depend on rainfed (non-irrigated) rice systems for much of their food production. It may thus be that rice-water regime is for rice-based food-production systems a better indicator of undernourishment and poverty than the climate-based agro-ecozones.

The cost of a rural workplace is substantially less than the cost of an urban workplace.

1.2 Forecasts: food requirements and production (including genetic) resources

1.2.1 Food production: achievements and forecasts

Notwithstanding the real concerns for continuing poverty and undernourishment in Asia, the *past achievements* of, and the *responsible forecasts* for, the rice-based livelihood- and food-security-support systems suggest that those systems shall be able to respond successfully to the challenges and the opportunities that shall occur during the oncoming thirty years. In some respects the future challenges to the productive capability of the rice systems shall be less severe than the challenges that were overcome during the past thirty years. Thus, past progress in many Asian countries in increasing the per-person calorie intake up to and much beyond the food-security threshold of 2 300 kcal/ day has lessened the requirement for high annual growth in food energy per person. Additionally, projected rates of population increase for 2001-2030 are appreciably less than those experienced during 1990-98.

Consequently, forecasts (FAO 2000d) for the required growth rates (2002-2030, and allowing for projected dietary changes) in production of major foods and food groups are less than those achieved -except possibly for some livestock products, and for food crops in some areas of degrading lands - during recent decades. However, some pertinent caution is expressed in chapter 2.1.1.

Overall, there is confident expectation (FAO 2000d) that there shall be a strong deceleration in the requirement for increased *food* production. However, there shall be substantially increased demand for livestock *feeds* - a consequence of the now ongoing "livestock revolution". Notably, for *maize* at Year 2020 as compared to 2000, Asia's *increased* (food + feed) requirement - to be met from imports and increased production - is forecast (CIMMYT 2000b, quoting IFPRI) to constitute some 60 percent of the global increase in maize requirement. This 60 percent proportion may be contrasted with Asia's proportion (27 percent only) of global maize production at 1996-99. Significantly, in China at 1995/97, more than two-thirds of all maize grain was fed to livestock; China is expanding also its production of multi-use feed/fodder/food crops such as sweet sorghum.

These several features are illustrated (in summary) in Table 3, where for rice, wheat, maize, soybean, and all food-crops, and globally and for East Asia and South Asia, the annual growth rates in production achieved during 1967-96 are compared with the projected requirements for 1996-2030.

Encouragingly, the human, biophysical, economic, and technological resources wherewith to address the future challenges are substantially greater than those that were available in the past. Notably, for crops and for livestock and *their systems*, the necessary diagnostic and management procedures are, or shall be, sufficiently developed and documented that through 2002-2030 the required levels of productivity, production, and hopefully income, shall be achievable.

Table 3: Growth rates (%/annun) in production: various crops and regional groupings: 1967-1996 or 1989-1999 (each actual) and 1996-2030 (forecast requirement)

Grouping	Crop Period	1967-96 or 1989-99*	1996-2030
Developing world	All	3.1	1.6
Developing world	Rice	1.5*	1.0
Developing world	Wheat	-	1.3
Developing world	Maize	-	2.0
Developing world	Soybean	-	2.6
East Asia	All	3.6	1.2
South Asia	All	2.8	1.9
East Asia	Rice	1.3*	-
South Asia	Rice	1.8*	-
East Asia	Wheat	2.3*	-
South Asia	Wheat	3.2*	-
East Asia	Maize	4.1*	-
South Asia	Maize	1.8*	-

[Notes: Source: FAO 2000d. For rice, the "Developing world" forecast effectively represents All Developing Asia; for wheat, Asia produces about one-third of the global total, and for maize about one-fourth; the growth-rate requirements for wheat and maize in Asia shall be higher than the Developing-World aggregate figures. Forecasts for the 1996-2030 growth rates required for oil crops and for green vegetables generally exceed 2.0 %/ann.]

The welcome expansion (UNESCO *via* UNICEF 2000) of *education* - including secondary education - permits expectation that with appropriate pro-grammes of training and extension the rice-system farmers and entrepreneurs of the early twenty-first century shall through enhanced literacy and numeracy be better prepared than their predecessors to take advantage of the available technologies, packages, and systems. Nonetheless, it shall be cautionary to acknowledge that the poorest and most food-insecure - and particularly

the rural girls and women and the orphaned survivors of HIV/AIDS victims among them - shall be the last to benefit from this expansion of education and its benefits.

Technologically: for the *major field crops,* whether for food, feed, fodder, or edible oil and oilmeal, there are strong indications that the various breeding and seed/planting-material multiplication programmes are already developing and releasing and shall continue to develop and release the cultivars that shall be required to meet the expanding and changing needs of the smallholder rice-based cropping systems.

For the *rice-farm livestock* - particularly for ruminants and poultry - there is similar confidence that quality breeds and stock of specification appropriate to the pertinent ecozones shall be available to support the forecast expansion in milk, meat, and eggs production. However, IFAD (2001) and Dixon *et al* (2001) highlight the continuing need for vigorous programmes to improve the productivity of those *staples* on which many poor persons depend.

1.2.2 Future production: driving forces and sources of growth

The country-specific *driving forces* that generate the requirements for production increases for the several foods and food products are threefold: (1) population and income growth (notwithstanding the difficulties of making definitive income-growth forecasts); (2) predicted changes in food-consumption patterns - for which reliable projections already exist, importantly in relation to animal : vegetable products balance, both for type and for quantity; and (3) technical-cum-social changes: future productive technologies shall be constrained within increasing concerns / awareness for environmental (agrochemical, land degradation, water pollution) and food safety issues.

These driving forces shall be complemented by *market forces:* these are likely to include pricing and taxes so as to increase use-efficiencies for water and for fertilizers - particularly if there is a continuation of currently high petroleum-product prices. They shall include also price-competitiveness for exports of rice and other products from rice-based systems. Thus Viet Nam already markets rice at lower price than Thailand, which shall likely respond in terms of quality rather than price. Viet Nam also markets potatoes more competitively than Indonesia - even in Indonesia-neighbouring Malaysia and Singapore.

Sources of growth in production during 2002-2030 for all food crops, including rice and rice-sequenced crops, for East Asia and for South Asia [for these two sub-regions, forecasts (FAO 2000d) are essentially identical] shall derive proportionately from increases in agricultural-land area and in cropping intensity. These sources together contribute 17 percent of forecast growth in food production, compared to 20 percent during 1961-97, and 83 percent from increases in crop yields and from more-efficient post-harvest processing and marketing, compared to 80 percent during 1961-97.

For both East Asia and South Asia, the 17 percent forecast growth ascribed to land area and to cropping intensity shall derive mainly from the latter - resulting predominantly from increases in irrigation facilities and their water-distribution efficiencies - since there shall be relatively little opportunity to increase arable-land area.

However, within East Asia, the statistics are dominated by China: thus while the forecast annual growth rate (1996-2030) for *arable land in use* is 0.07 % / ann for all East Asia, the corres-ponding rate for East Asia excluding China (essentially South-East Asia) is 0.41 % / ann: representing a 15 percent increase during 34 years. The forecast land-growth rate for South Asia is 0.13 % / ann - effectively all in India.

The FAO (2000d) forecasts acknowledge that for *rice irrigation,* the economically and environmentally appropriate options have already been utilized, and that more efficient irrigation management procedures for existing facilities are both required and possible; chapter 3.4.2 summarises Asian prospects for irrigated-area expansion. Pertinently, appropriate investments in the rainfed-lowland-rice systems may expect to contribute both to cost-effective increase in rice production and to a lessening of hunger, poverty, and environmental degradation. For *rice yield,* the implication is that the 1995/97 global-average value (aggregate for irrigated and rainfed systems) of 3.5 t / ha shall need to increase to 4.6 t / ha by 2030.

However, notwithstanding the justifiable emphasis in this report, and in much of the rural livelihoods literature, on crop and livestock yields, IFAD (2001) wisely cautions that for very poor farming households

the priority is *not* yield - but the lessening of risk, and the preservation of their resource base. Nonetheless, the requirements for regional food security do dictate that yields and yield potentials must be raised continually.

Thus, and overall, future increases in Asian rice-system production shall depend strongly on increases in crop and livestock and food products *yields per unit land area, and per unit of other natural and human resources, and per unit time and per unit of purchased resources including fertilizers and water.* The outlooks for such increases are fortunately encouraging.

Outlooks are similarly encouraged by recent analyses (Singh, Kumar, and Woodhead 2002) that indicate that for eighteen crops in various Indian states the total factor productivity is for all crops, and excepting only a very small minority of states, either *constant or increasing*. Correspondingly, for the total factor productivity for *rice production* in India, Singh (2001a, quoting IARI/ACIAR) reports that the effective contributory *interventions* have been infrastructural constructions, agricultural research and extension, literacy (education), and irrigation.

For *all-crops* production in Southern China, FAO (1998b, citing World Bank 1997) suggests that research investment and institutional reform comprised the more-effective interventions, while for *wheat* production in Northern China, effects of institutional reform were paramount. Similarly, for *wheat yield* in India, the prominent determinants have been irrigation, wheat price, and technologies, and for *rice yield:* price, technologies, and electrical power. However, for the rice-wheat systems in Bangladesh, IRRI (2001a) reports that agroclimatic and technological factors - and not economic factors - constitute the major determinants of productivity. Similarly for the *unfavourable* rice-wheat areas in the Indo-Gangetic Plains, IRRI (2001a) concludes that prices of rice and wheat are *not* dominant constraints to wheat-productivity growth.

For the countries of *Indo-China* (Cambodia, Laos, Myanmar and Viet Nam), concern has been expressed (FAO 1998b Box A) that the sources of growth may be insufficient to maintain food security and poverty reduction: rural transport and communications and irrigation are deficient (though Cambodia, in particular, has abundant unused land and water), the human capital is at a rudimentary stage of development, and there is, within a general lack of peace and order, a weak enforcement of rights to property and to tenure.

1.2.3 Yield trends and yield-potential increases

The topic of *time-trends in crop yields*, and particularly for irrigated-rice yields, has in recent years been much subject to analysis: including conjecture (IRRI 2000) that nitrogen may be immobilized by phenols within the lignins that accumulate in continuously submerged soils. Regrettably, there has also been some irresponsible economic analysis concerning rice-yield trends.

Definitively, recent surveys for rice have reported (IRRI 2001a) that *"on 75 Mha of irrigated rice farms there is no evidence of rice-yield decline"*. Likewise, Singh (2001b Table 20, adapting FAO 2000d) indicates that throughout the 1960s, 1970s, 1980s and 1990s, there were consistent annual yield increases of about 45 kg / ha.crop for *rice* in South-East Asia, and similarly of about 45 kg / ha.crop for *wheat* in South Asia. Correspondingly, FAO/RAP Indicators for Asia (FAO 2000b, 2001b) indicate that - for almost all Asian rice-growing countries - crop yields and indices of agricultural and of food production - from an essentially constant-area resource base - continued to increase throughout 1995-1999 - notwithstanding *El Nino,* floods and cyclones, and regional economic crises.

[However, FAO (2001c, 2001d, 2001e) reports that global (and Asian) rice production in Year 2000 was 3 percent less than in 1999 (and less also than the Year-2000 consumption), and 1 percent less in 2001 than in 2000. This decreased production was in part a consequence of slackening consumer demand, and some crop failures, and particularly of declining rice prices: between Years 1997/99 and 2000, the FAO rice-price index declined from 123 to 98 (its lowest value since 1987), and subsequently to 88 in May 2001, with a slight recovery to 90 in August 2001.

But notwithstanding this decreased production, there was sufficient rice surplus during 1998-2000 that

there were record totals of international rice-food aid, substantial national distributions of rice (free-of-charge) to very poor families, and record contributions to the World Food Programme's International Emergency Food Reserve and to its Relief Action Reserve.]

Crucially, the suspicion of yield declines in *long-term experiments* for irrigated rice-rice and rice-wheat sequences has been *firmly dispelled* by a highly competent all-Asia analysis for 30 sites in 9 countries (IRRI 2000, FAO 2001f), from which Greenland (*via* IRRI 2001a) was able to conclude *"so far are as there is any yield-decline in appropriately-fertilized rice in long-term experimental studies, such declines are episodic and atypical"*. By this author's direct field observation, such reported declines derived sometimes from poor-quality experimentation.

Moreover, in well-conducted long-term rice-fertilization experiments, where rice yield does decline in deliberately under-fertilized treatments, the time-trend in yield should be portrayed not as an (unrealistic) linear decline, but should rather be quantified (Woodhead, in IRRI 1994) through an inverse-sigmoid function. Such function can similarly describe the decline in annual off-shore fish catch in an over-exploited system (BCEOM 2000).

Long-term analyses of *time-trends in national-average yields* of rice (and of other crops) should necessarily take account of the steadily-decreasing length of time (transplanting/seeding-to-harvest) during which an individual crop utilises the natural and human resources of land, water, solar irradiance, and farmer management and finances. Such analyses should thus be pursued in terms of *yield per field day*, and not of yield per crop season. Indeed, breeders' and agronomists' analyses of IRRI cultivars and breeding lines and their yield potentials did in earlier years make and publish such analyses.

Table 4: Yield potential of irrigated rice in tropical ecozones: 1970 - 1990 - 2010

Epoch	Cultivar	Seed-to-seed duration (days)	Yield potential (kg / ha)	Yield potential per day (kg / ha.day)
1970	IR8	150	10 000	67
1990	Various *indica*	130	10 000	77
2010	New plant type	130	12 000	92

[Source: Various.]

Applying this methodology, the tentative analysis in Table 4 constitutes a powerful riposte to the yield-potential-stagnation pessimists. For transplanted rice, the comparisons are even more compelling when determined for days from transplanting to harvest. Yield-per-field-day analyses will also quantify the benefits (as in China - Wang and Guo 1994) of double transplanting (first in seedbed nursery, then in intermediate nursery, whence to the final-harvest field) so as to optimize opportunities, in reliably-irrigated systems and where economic, for rice-rice-rice and rice-rice-wheat and other similarly intensive high-income sequences. Such double transplanting systems may permit also a concentrated and effective control of seedling-stage golden-snail infestations.

For most Asian rice-growing countries, data series for *national-average rice yields* (irrigated and non-irrigated in aggregate) extend throughout 1960-1999. Such series permit of *trend analyses* throughout the whole 40-year period and for the component (usually 10-year) segments within that period. For such periods and segments, the yield-trend statistic that is most generally calculated, published, interpreted, and used in *policy deliberations* is the annual compound growth rate calculated on the assumption that such statistic remains constant throughout the particular period / segment. If for long-term data series this statistic is less for later components than for earlier ones, concerns may (unwarrantedly) be expressed that "there is decline in yield, or decline in the growth rate of yield, or more plausibly - a deterioration in the resource system".

Such concerns usually do not allow for the feature that yields for later time segments may relate to shorter-duration cultivars than those for which yields were recorded during earlier time segments, and that yield / day, representing *efficiency of using resources* - including genetic and human resources, may have been *sustained or even increased*.

Nor do such concerns acknowledge the inevitable aspect of diminishing returns - for which some evidence is provided by Siddiq (2000, p.19) in his analyses of the annual rice-yield and wheat-yield growth rates in some

Indo-Gangetic rice-wheat districts during 1980-98. Siddiq demonstrates convincingly that in those districts for which initial (1980-82) yields were comparatively high, subsequent yield-growth rates were comparatively less than in those districts for which initial yields were low. Farmers in the districts having higher initial yields may be presumed to have had earlier access to facilities, resources, and technologies that permitted comparatively high yields; FAO (2001a) suggests that in India such districts comprised no more than 10 percent of the total number of districts. Correspondingly, those districts, the great majority, with lower initial yields were subsequently able to achieve comparatively higher growth rates as they in turn gained access to the pertinent technologies and resources - notably irrigation and electricity. For both categories of district, there is implication that as the gap between farm yield and *potential yield* lessened, so also did the ability to achieve high annual rice- and wheat-yield growth rates.

However, in rice-growing environments having low natural- and economic-resource endowments - notably the rainfed uplands - yields of rice and of non-rice crops do stagnate and/or decline as a result of soil degradation - particularly soil erosion. This still continuing degradation derives not from deliberate choices of farm families - who are well aware of the value of their land resource, but from the prevalence of an array of economic, social, and political pressures (FAO 1999b, Dixon *et al* 2001).

Against these pressures, well conceived and appropriately long-term-financed interventions that apply proven methods of sustainable and farmer-participatory resource management can expect to prevail. FAO (1999b) and IFAD (2001) cogently argue that appropriate sustainable agricultural resource management (SARM) and/or Improved Land-Management Technology (ILMT) not only conserve and restore fragile resources but also contribute to long-term poverty alleviation. FAO (1999b) correspondingly reasons that a continuance of natural-resource degradation shall threaten the livelihoods of families, and ultimately of nations.

Moreover, recent analyses (Singh, Kumar, and Woodhead 2002) suggest that for some countries there may be well-founded concern that the rice-yield growth rate has slackened more than was previously realized. These analyses, with supplementary graphical smoothing, determined the *rice-yield* growth rate during each of the six-year segments 1964-70, 1970-76, 1976-82, 1982-88, 1988-1994, and 1994-2000. For *India*, the sequence of those growth rates was 1.7, 1.7, 2.2, 3.3, 2.5, and 1.4 % / ann. For *all-cereals* in aggregate, and for the six-year segments 1970-76 through 1994-2000, values were 1.8, 2.6, 3.2, 3.6 and 1.9 % / ann.

Thus in the late 1990s, the growth rates for rice yield and for all-cereals yield, though creditable, are lower than at any time since 1960, and are substantially below their late-1980s respective peaks of 3.3 and 3.6 % / ann. These declines may constitute in part a response to diminishing demand for rice and to inadequate returns to farmers: globally, the Year-2001 world price for rice was the lowest since 1998; and in India, the strategic buffers were fully stocked. This slackening in yield growth rates may result also from several other causes: from a lessening of inputs as farmers responded to falling prices, or from non-increase in inputs where farmers had already optimized their inputs applications, and from some progressive closing of yield gaps in some states.

The 1994-2000 growth rates, at 1.4 % / ann and 1.9 % / ann, are only marginally higher than the forecast *human-population* growth rate (1996-2010) of 1.3 % / ann. Moreover, a projection of the 1988-2000 trends suggests that each of those growth rates may indeed fall below 1.3 % / ann during 2002-2004. It is therefore perhaps comforting to note that for India, the proportion of rice in the total kcal/person.day is slightly less than one-third, and of all cereals less than three-fifths.

For *Bangladesh*, however, the proportion of rice in the total kcal/person.day is *three-fourths*, and of all cereals more than four-fifths. It is thus reassuring that for Bangladesh the *rice-yield* growth rate during the six-year segments 1964-70 through 1994-2000 was 0.2, 1.4, 2.0, 2.3, 2.6 and 3.4 %/ann. The latter, seemingly increasing values are substantially higher than the forecast *human-population* growth rate (1996-2010) of 1.5 % / ann. Bangladesh was perhaps some few years later than India in adopting the newer technologies and the free market policies that have contributed to this hopeful situation.

The preceding paragraphs imply that progressive increase throughout 2002-2030 in *potential yields for rice and for associated crops* shall be required to contribute strongly to the necessary growths in food production. Encouragingly, there is firm indication that the strategies and procedures to achieve such potential-yield increases are already operational and successful.

Thus for *rice*, "new plant types" have been conceived for irrigated and for rainfed-lowland rice-production systems (IRRI 2001a). The new plant type for irrigated systems is expected to have a yield potential in *tropical Asian irrigated* ricelands of 12 t/ha - compared to 10 t/ha for the *indica-type* conventionally-bred cultivars widely grown at 1998-2000. In farmers' fields, this increased potential should result in Asian-average irrigated-rice yield progressing from 5 to 6 t/ha. For *rainfed-lowland* rice systems, the corresponding new plant type is expected to have a yield potential in *tropical* regions of 5-6 t/ha, and shall be able to survive repeated and prolonged submergence and drought.

For sub-tropical wheat and maize, similarly, new plant types are under development. There is already the capability to choose rice and wheat and maize cultivars of field-durations appropriate to specific cropping systems in particular locations/agroclimates, and to choose cultivars, of various crops, for particular consumer preferences: glutinous/non-glutinous rice; bread and non-bread wheats; maize and oil-crops for feed, fodder, fuel, or food. For rice, the new plant type is already released to farmers in some provinces of China. It is currently undergoing final stages of location-specific evaluation in several other rice-growing countries; and locally adapted versions are expected to be available to those countries' farmers by 2005.

China - where farmers used semi-dwarf rice cultivars *before* the advent of the Green Revolution - has featured also (FAO 2000e) as the main source of technology and of experience for *hybrid rice*. Initially, and as a result both of highly competent breeding and science and of government directives and subsidies, hybrid rice helped substantially to raise national-average rice yield by 15 percent during 1985-95 - thereby lessening the pressure on the agricultural-land resource by enabling the area of riceland to decrease from 36 to 32 Mha, while producing sufficient rice for food-security needs. Additionally, hybrid-rice seed-production enterprises created much rural employment (Singh 1997).

However, within the current Agricultural Reform Period, and in consequence of consumers' judgement that hybrid rice has inferior eating quality, and of Chinese farmers' experience that its production was unprofitable, the area of hybrid rice in China, which at 1990 comprised one-half of the total rice area, has in recent years declined (Husain *et al* 2001). Similarly in other countries there has been farmer and consumer resistance to the adoption of hybrid-rice technology: thus in India, hybrid rice was in 1998 grown commercially on 0.18 Mha only - compared to an expectation of 2.0 Mha.

Conversely, there are currently 0.30 Mha of hybrid rice in Viet Nam, and 0.015 Mha in the Philippines. In Bangladesh, with 0.03 Mha of hybrid rice, initial farmer-participatory trials of China-produced hybrids have indicated a measure of farmer acceptance - in part because of high yield and profitability (Husain *et al* 2001) - such that farmers have voluntarily extended the initial trials.

Thus, anticipating progress in improving eating quality, then *(indica)* hybrid rice - with its 15 percent increase in yield potential (Papademitriou, and Duwayri *et al*, each in FAO 2000c, quoting Khush 1995) - might be expected to be widely used in several tropical regions by 2010. For the sub-tropics, higher-yield-potential *japonica* hybrids are under cultivation in northern China. Also by 2010, there is reasonable prospect that cultivars shall be available that combine the attributes of the *(indica)* hybrid rice with those of the new plant type, and which thereby generate a (tropics) yield potential of perhaps 14 t/ha. As a general observation - with particular relevance for natural- and purchased-resources management - it is perhaps worthwhile to recall that high yield potential, and corresponding high on-farm yields, represent a more-efficient and hence more profitable usage (compared to heretofore) of water, nutrients, and solar irradiance.

[FAO, through various technical cooperation projects, has helped provide training, facilities, and genetic materials for hybrid-rice development in Bangladesh, India, Indonesia, Myanmar, the Philippines, Sri Lanka, and Viet Nam.]

Similarly, for *maize and wheat* (IFPRI 1998e, CIMMYT 2000a and 2000b) - and to a lesser extent for other rice-system crops - ongoing and new programmes are expected to develop (during 2002-2030) cultivars with the required yield potential. Indeed, maize and wheat hybrids are already in use in several countries, and as with rice, so with tropical maize and wheat, there are programmes to design and develop new plant types.

1.2.4 Applications of biotechnology

For poor persons, there is need to raise the yields of staple food crops; such need may necessitate the introduction of genes from other species. But as IFAD (2001) contends: *"Though the scientific (biotechnological) prospects are excellent, they are at present limited by the focus of research on a form of*

agriculture that caters mainly to rich people in rich countries, and not to the food needs of the world's poor." Helpfully, expanding programmes in China are seeking to redress this imbalance.

It is therefore pertinent to advise that two of the five multi-disciplinary thrusts of FAO's programmes for the Asia-Pacific region respectively address *Biotechnology, biosecurity, and biodiversity,* and the *Rice-based livelihood systems and their role in lessening hunger and rural poverty.* The three other thrusts are also relevant to livelihoods and to smallholder agriculture; they address *World trade and policy environment; Livestock intensification;* and *Disasters preparedness and management.*

Thus, and notwithstanding the valid concerns of IFAD, the fore-mentioned breeding programmes for rice, for maize and for wheat do include collaborative networks (for Asia) to harness the proven and emerging techniques of *biotechnology*. For the medium term, crop-genome maps, and procedures of molecular breeding, using gene-pyramiding and gene-marker procedures, should each be available at Year 2010 to support the ongoing breeding programmes. Indeed, for rice, there were already (April 2002) listings of the draft DNA sequences for both the *indica* and the *japonica* eco-geographic races. *[The ongoing and prospective applications of the biotechnological techniques of embryo rescue, anther culture, molecular-marker-aided selection, transformation (various methods), and DNA finger-printing were listed and described in Singh 1997 and in IRRI 1997 Chapter 6. The April-2002 sequences were determined using the "Whole-Genome Shotgun Technique".]*

These breeding programmes - both conventional and biotechnological - shall address not only the issues of yield potential, but also those of biotic and abiotic constraints to yields in specific agro-ecozones. Thus in the nearer term (2002-2005), and for the devastative *rice-tungro* virus, newly-developed breeding lines and cultivars are likely to provide substantially-increased resistance to the transmission vector (green leaf-hopper) and to the virus itself. For *maize,* the Asian biotechnology programme expects impact, perhaps by 2010, in producing cultivars suited to the drought-prone infertile uplands. For *wheat,* there is already a herbicide-resistant (transgenic) cultivar, and there are expectations for cultivars resistant to stem and leaf rusts, spot blotch, and barley yellow dwarf virus, and tolerant of acidic water and soil.

As a contribution to human *micro-nutrition,* rice cultivars (IRRI 2001a) are now available that contain nutritionally-beneficent concentrations of vitamin-A, or of iodine, of iron, or of zinc. Grain from such cultivars might provide a useful complement to food fortifications in helping combat the human ailments (particularly in poor people) that result from deficiencies in those micro-nutritional entities.

Cultivar development shall contribute also to sustainable and efficient use of production resources. Short-duration and drought-tolerant *maize* may expect to contribute strongly to the expanding production of livestock feeds in rainfed rice-maize systems. Similarly, there may by Year 2010 be *rice* cultivars specifically suited to direct seeding - thereby providing opportunity for water economy in an increasingly water-scarce Asia.

Similarly, for economy in *fertilizer use,* there are N-efficient *rice* cultivars already available in various countries; wider adoption of such cultivars might be prompted by any substantial and sustained increase in the prices of petroleum products and hence of urea and ammonium fertilizers. By 2020 (or perhaps 2030), there is realistic prospect that *rice* cultivars shall be available that can fix substantial amounts of atmospheric nitrogen. Thus FAO (2000c, quoting various sources) suggests that there is potential to fix 200 kg N / ha.crop using biotechnology-assisted procedures of induced symbiosis and of transfer to rice of the several nitrogen-fixing (nif) genes. However, it is necessary to be mindful that the incorporation of nif genes may incur an unacceptably high (physiological) rice-yield penalty.

In this context, a 10 t-grain / ha new-plant-type rice crop shall indeed require to accumulate about 200 kg N / ha.season, at a seasonal-average rate of about 2 kg N / ha.day, and at an appreciably higher rate at times of vigorous crop demand for N. Such atmospheric-N-fixing techno-logy would have twin benefits of being a seed-based input with high probability of on-farm adoption, and of lessening nitrogen impacts to the environment. Correspondingly, there would be crucial requirement for a balanced (and substantial) input of non-nitrogen nutrients and micro-nutrients. Box 2 highlights the progressive development of micro-nutrient deficiencies in intensively cropped Asian soils.

For *rice* for the longer term (2020-30), there is possibility that programmes already ongoing shall have created rice plants that can utilize the C4 rather than the C3 cycle of photosynthesis, bringing prospective increase in

individual-leaf photosynthetic efficiency - and hence in crop photosynthesis and in resource-use efficiency, and possibly in yield potential - more notably for non-submerged, rainfed, fields and their marginal farmers.

For *upland* (non-bunded) ricefields - where purchased-input use is currently minimal - there may by Year 2020 be cultivars that have resistance to *rice-blast* fungus and that can tolerate / escape drought. Indeed, long-established upland-rice breeding programmes have a new impetus to develop *"aerobic rice"* cultivars. Significantly, there may also by 2020 be viable cultivars of perennial rice that will both produce grain and also, if contour-planted, provide erosion control on fragile sloping lands: IRRI (2001b) reports that initial breeding materials, of which the "perenniality" parent is *Oryza rufi-pogon,* should by 2005 be available for evaluation/ adaptation by national-system partners. Moreover, some of those initial materials may by unexpected outcome (IRRI 2001b) have photosynthetic rates that are more akin to those of C3 than of C4 plants.

1.3 Natural-resource endowments and pressures

In meeting the production-oriented rice-system challenges, there shall indeed be vital need for major inter-disciplinary efforts and programmes to ensure the conservation and regeneration and rehabilitation of the *natural-resource endowments* of the ricelands and of adjacent (often fragile) lands. There shall be need also to cope with the increased pollution loads - solid, liquid, and gaseous - and the prospective land and water degradations that shall result from the forecast changes in farming systems and practices. Simultaneously, the rice-dependent communities and enterprises shall encounter both opportunities and challenges as the impacts of *world-trade agreements* become more intense and widespread.

1.3.1 Land endowments and pressures

For the ricelands' *natural-resource endowments,* issues of *land access,* of *nutrients and soil* management, of *water* availability, and of *sustainability* are paramount (ADB 2001a 2001c, World Bank 2001a, Dixon *et al* 2001, IFAD 2001). *Rice area per person* was in 1961 about 0.12 ha / person; by 1998 it had decreased to 0.07 ha / person. *Average size* of rice-farm holding also decreased between those dates - in part, and beneficially in relation to equity and poverty alleviation, through deliberate programmes of land reform/ redistribution, and in part, but less beneficially, through inheritance-related over-fragmentation of already-small holdings. [In comparison to a total rice-harvest area of ≈ 135 Mha, the much publicized loss of land to peri-urban development is not serious: even in populous Indonesia, rice-harvest area increased at 1.2% / ann during 1990-2000.]

Rice-production projections to Year 2030 assume that increased productivity and income per unit of land will compensate for decreased land-area/person and for increased land fragmentation, but that immense, externally-assisted, efforts shall be needed to introduce and operate policies that strengthen property and water-use rights, that correct tenurial anomalies, and that promote effective land markets (FAO 2000g, World Bank 2001a) and that provide to the rural landless - and to women (IFAD 2001 Box 3.8) - the means to participate in those markets.

Historically, among *East-Asian* countries (FAO 1998b Annex 2), Indonesia has re-settled, though not without problems, about 1.5 M landless families from Java in various of its other islands; Malaysia had a similar, though much smaller programme of land allocation to landless families; the Philippines has a long history of land-redistribution programmes, but the proportion of landless tenants and labourers remains high; as it does in Thailand also. In the socialist systems of China and Viet Nam, land ownership is usually retained by the State, but tenancy rights - saleable and/or transferable - can be granted for periods of 20 - 50 years.

For the global *environment,* global agriculture is a prominent source (FAO 2000d) of nitrate in ground- and surface-water, and of phosphate in waterways. It is a substantial source of ammonia that contributes to acid rain, and hence to tree damage, to eutrophication of ecosystems, and loss of biodiversity; a source also of the greenhouse gases methane and nitrous oxide. Of the annual anthropogenic atmospheric inputs, agriculture, with rice-lands prominent, contributes about 80 percent of nitrous oxide, and some 40 percent of methane. In the rice-based *crop sequences,* both the rice and the non-rice crops may, through inappropriate fertilization, contribute to those pollution processes; they may also cause excessive extraction ("mining") of nutrients. Procedures of site-specific nutrient management may help combat these deleterious processes.

Global agriculture is also the largest consumer of *diverted water.* In rice ecozones, the abstraction and application of some part of that diverted water contributes to soil salinization and to groundwater depletion. Fortunately, improving technologies are expected to contain these problems during the medium term (FAO 1997a, 2000a, 2000d).

In the uplands - including upland ricelands - inappropriate soil management is the cause (Dixon *et al* 2001) of much soil erosion, and hence of downstream siltation, of mudslides, and of dry-season water scarcity and hence of decreased yields. FAO (1999b) suggests that much previous effort to counter soil erosion in developing countries has been ineffective, and that soils continue to erode. The methodologies of sustainable land management correspondingly urge the adoption, and sponsorship, of the techniques and concepts of *"good land husbandry"* (including crop-nutritional husbandry) within integrative development programmes that address pertinent institutional and policy aspects and that strengthen efforts in extension and training.

Crucially, such programmes must ensure that the economic benefits accrue to the implementing farm families, and not to off-site (perhaps down-stream) communities, and must ensure also that the implementing families have guaranteed rights of land usage and/or tenure, and hence the incentive to invest their labour and their financial resources.

In the lowlands, the bunded ricefields provide effective soil-erosion control. This feature may in part explain the encouraging statistic (FAO 2000d, quoting Oldeman 1998 and other sources) that during the 45 years 1945-90, Asian crop-land productivity is estimated to have decreased as a consequence of land degradation by only 13percent - little more than the 9percent calculated for Western Europe and North America. Aesthetically, the extensively terraced hillside rice systems maintain a pleasing rural landscape. Agriculture also has the important potential to sequester - as well as to emit - pollutants.

1.3.2 Livestock aspects

Livestock systems (small-scale, and large-scale, and increasingly stall-fed) are forecast (LEAD 1999, FAO 1999c, 2000d) to impose increasingly intensive and extensive pressures - during 2002 to 2030 - on local and global environments. The increase in demand for feeds is likely to be met in large part by *coarse grains,* for which much of the increased production shall be from rainfed systems - including upland and lowland rainfed-rice-based systems, and perhaps pre-monsoon in some floodprone lands. Some of those rice-system uplands shall be on fragile lands highly susceptible to soil erosion and to losses and mining of nutrients; moreover, a concentration of coarse-grain production is likely to lessen ecosystem biodiversity.

The greater environmental threat from livestock, however, is posed by the animal *excreta:* whether solid, liquid, or gaseous. Indeed, LEAD (1999) reports that the external costs of these excreta is generally more substantial than previously realised, and that in East Asia excessive applications of animal wastes to farm-lands are already causing nitrate pollution of groundwaters.

For the *solid and liquid excreta,* management shall expect to be enterprise-size-dependent: in diversified ("mixed") crop / livestock smallholdings, management may expect to recycle much of the material, using improved versions of traditional systems (as in China and elsewhere). Relatedly, LEAD (1999) suggests that strengthened land-tenurial arrangements lessen the adverse, and promote the favourable, environmental impacts.

For the larger, specialised ("industrial") livestock enterprises, which are forecast to become increasingly more numerous - and to make increasing use of concentrate feeds - containment and disposal shall be more technical and costly. Disposal shall be likely to cause soil acidification, shall probably require legislation and enforcement (ADB 2001c), and might expect to adopt and adapt appropriate procedures from developed-world husbandry - including (LEAD 1999) the procedures of "polluter pays" and of "tradeable emissions".

For the *gaseous pollutants* from livestock exhalations and excreta - products of enteric fermentation, and of breakdown of dung and urine on pastures and croplands and in collection pits - livestock shall contribute dominantly to the increases (2002-2030) in anthropogenic emissions of methane and nitrous oxide, and of ammonia.

Methane emission by livestock - already at Year 2000 a substantial component of anthropogenic methane - is forecast to increase in East and South Asia during 1996-2030 from 21 to 49 Mt / ann (corresponding global

totals being 79 and 128 Mt / ann). Proportionate increases in *rice-crop methane emissions* are forecast to be substantially less than these forecasts for livestock.

For *nitrous oxide*, livestock-generated emissions are expected to increase globally by about one-half during 1996-2030 (FAO 2000d, adapting from Mosier *et al* 1996). For anthropogenic *ammonia* - to which livestock is a major contributor - proportionate increases (2030 compared to 1996) are forecast as x1.7 for East Asia, and x2.1 for South Asia, compared to a global average of x1.6. The differential increases as between East and South Asia reflect differential (forecast) population increases among the types of livestock: major increases in beef cattle / buffalo, sheep / goats, and poultry in East Asia, and in poultry, dairy cattle, and sheep / goats in South Asia. For each of these forecast increases in livestock-generated pollution, some part shall derive from increased numbers in *rice-farm livestock.*

1.3.3 Land-use, agrochemical and global climate aspects

Rice-farm systems shall also be the victim and the beneficiary, as well as the cause, of future land-use changes and *environmental impacts* - including climate-change impacts. Thus - and with implication for food security and rural environments - there shall be continuing loss of productive agricultural land to urban, infrastructural, and industrial developments.

Such environmental and food-security impacts may be illustrated (FAO 2000d) by experience in China: food produced heretofore through triple- and double-cropping on southern-provinces productive land that has been lost to agriculture has required to be substituted (but only in part) by food grown in single-crop systems in north-eastern provinces on less-productive (previously pasture) land.

Conversely, the transformation of lowland wetlands - themselves under intense and persistent anthropogenic pressures - into rice-system-lands has, as in China, Indonesia and elsewhere, destroyed the functions and economic values of those wetlands - including their contributions to biodiversity and habitats and to off-shore fisheries. It has lessened also the wetlands' function of flood regulation - which will be restored only, and if at all, by extremely high-cost and environment-unfriendly engineering interventions. And for many low-lying coastal ricelands, whether transformed wetlands or otherwise, the impending sea-level rise shall bring increased salinity and decreased yields.

Pesticide applications, increasing typically at 4 to 5 %/ann, bring mixed blessings to agriculture's environments. Rice-farm operatives and non-target ricefield organisms suffer pesticide-induced morbidity and mortality; and much applied chemical fails to reach the target plant; and the target pests progressively develop resistance to the pesticides.

However, it may be construed that ricefield pesticides in aggregate preserve 10 percent (about 40 Mt / ann) of Asian irrigated-rice production that would otherwise be lost. Thus, foregoing those pesticides would require, at representative yields of 5.0t/ha, irrigated, and 2.5t / ha, rainfed-lowland, an additional 16 Mha of irrigation for previously rainfed-lowland riceland - not likely to be constructed imminently - or 16 Mha of new rainfed riceland, if such could be found, to make good the deficit. Alternatively, and assuming, with much doubt, that currently irrigated riceland is sufficiently underfertilized that there might be an incremental 5kg grain / kg fertilizer-N response to additional nitrogen fertilizer, then the currently-irrigated-rice area would require to receive in aggregate about 8Mt / ann additional N, or 17Mt / ann additional urea - compared to the current total of about 33Mt urea / ann.

None of the three foregoing alternatives seems to be any more environment-friendly than the current pesticide-using technology. It thus seems preferable and probable that improvements in pesticide application should be sought that lessen unnecessary and excess usage. Such improvements may or may not accommodate the feature that genetically modified crops shall provide an opportunity to lessen pesticide applications without loss of yield. It is pertinent that for maize, pepper, rape, soybean, and tomato - each candidate rice-system crops – genetically modified cultivars are already commercially grown in some parts of the world.

Currently, procedures of judicious pesticide use may be encouraged through programmes of taxation, training, improved local-language labelling / instructions on proprietary products, and perhaps through an expected increase in consumer concern for food safety. The methodology of integrated insect-pest management - of which FAO has substantial and successful experience, particularly in Asia - shall be particularly pertinent.

Among benefits brought to agriculture by *anthropogenic climate change* has been the increase in rates of photosynthesis, and hence of primary productivity of cropland - including riceland, that has resulted from increased atmospheric concentrations of carbon dioxide. For livestock enterprises, global warming holds prospect that the requirements and costs of animal housing shall in some ecozones be lessened.

Overall, FAO (2000d) opines that the increased environmental stresses that shall result from climate change and from the requirement to increase food production shall be countered by progressive improvements in tropical-agriculture technology and by suitable adaptations of environment-conserving procedures developed and validated in industrialized countries. Introduction of technologies and actions to correct perceived problems would expect to be guided by the Precautionary Principle.

FAO (2000d) also opines that the *average* effects of climate change (by Year 2030) shall be much less than the effects of economic and technological change - but that tropical and sub-tropical ecosystems, and the poor communities dependent upon them for food security, shall be at risk from increased frequency and severity of extreme events. Strategic aspects of some of these features, and of carbon-sequestration and fuel-biomass production, are re-visited in chapter 4.5.4 of this document.

[The various technical divisions of FAO (2000a) - including their Asia-Pacific-located groups - have vigorous ongoing "regular" programmes, (and support various operational Asia-Pacific networks) wherewith to assist governments and communities to address these several pressures, challenges, and opportunities.]

1.4 Smallholder contributions to food security

1.4.1 Farm-size dynamics

As indicated earlier, *average farm size,* inclusive of rice and non-rice farms, is decreasing throughout Asia; in India during 1971-1991 it decreased from 2.3 to 1.6 ha. However, a penetrative analysis by Kumar (Singh, Kumar, and Woodhead 2002) quantifies the many positive and beneficial effects of that continuing farm-size change. The analysis demonstrates that though the national-average farm size decreased, this was *not* the result of the fragmentation of already-small holdings, but represented a net transfer of about 27 Mha of land from units larger than 4.0 ha to those smaller than 4.0 ha.

[IFAD (2001) similarly suggests that: "Concensual land distribution is a promising way forward, with the largest farmers attracted to sell land in small amounts to the poor; but it requires some land fund in support"]

Moreover, Kumar's analysis indicates that because there was higher cropping intensity when the land transferred into smaller-unit operations, the transfer resulted in an increase in the area of "net cropped land" from 160 Mha to 180 Mha. Crucially, as a consequence of the land transfers, the *number of holdings* of area < 0.5 ha (the *sub-marginal* holdings, roughly analogous to the "functionally-landless" category in Bangladesh) increased from 23 M (23 million) to 43 M, and the number having area 0.5 - 1.0 ha (the *marginal* holdings) increased from 13 M to 21 M; the numbers of *small-* (1.0 - 2.0 ha) and of *medium-* (2.0 - 4.0 ha) size holdings increased respectively by 10 M and 9 M. That there was not substantial land fragmentation is manifest by the *constancy,* as between 1971 and 1991, of the *average* size of holding within each size category: sub-marginal 0.23 ha, marginal 0.73 ha, small 1.4 ha, medium 2.8 ha.

These conclusions may have relevance for other South-Asia countries. It is thus pertinent to list (from FAO 1998b Annex 1) for the South-Asian countries the proportion of cultivated land that is constituted by holdings *smaller than 1.0 ha: Bangladesh 20 percent, India 15 percent, Nepal 17 percent, Pakistan 2 percent (only), and Sri Lanka 20 percent [Though for Pakistan, IFAD (2001 Box 3.2) reports that 11 percent of cultivated land area is composed of units smaller than 2.0 ha.]*

Notwithstanding its smallness, 0.23 ha of farm-land (roughly half the size of an association-football field) constitutes a powerful resource wherewith a *rural-landless* family can escape poverty. In which context FAO (1998b Annex 1) reports that South-Asian countries have the following proportions of *rural-landless* households: *Bangladesh 20 percent, India 30 percent, Nepal 18 percent, Pakistan 30 percent, and Sri Lanka 22 percent.*

[In India, and probably in other countries also, more than half of the landless families are poor families. For Bangladesh, IFAD (2001) quantifies the inverse correlation between size of land-holding and incidence of poverty. For both South Asia and East Asia, IFAD (2001) reports that a substantial and increasing amount of

land is rented and farmed, successfully, by landless families, and that such renting generates rural employment. However, Dixon et al (2001) caution that the practice of share-cropping - wherein landless persons receive a defined portion of the harvest in return for provision of labour to a land-owning farmer - is an impediment to progress and to poverty reduction. Somewhat similarly, IFAD (2001) suggests that for the poor rural landless there is need for a specific research agenda / methodology.]

Importantly, and as stated by Agarwal (1994) and Swaminathan (2000) (each quoted by Singh 2001a): any piece of land, however small, for which a rural family - and particularly the woman of that family - has ownership or confirmed usage rights, is a vital asset in the pursuit of dignity and in the struggle against deprivation and child undernourishment. Similarly, a family that can produce even small amounts of its own calorie requirement - and notwithstanding that it may sell rather than consume some of its most-nutritious products - is correspondingly less likely to be poor and/or hungry (Singh 2001a, Table 16).

Kumar's analyses (Singh, Kumar, and Woodhead 2002) quantified also the extent to which (Indian) farms of differing sizes contributed during 1971-1991 to national food security - both through satisfying some or all of their own household's food requirement, and also through supplying surplus food to the markets and prospectively to the emergency buffer stocks.

Thus between 1971 and 1991 there were the following increases in the percentage contribution to total national production made by farms *smaller than 2.0 ha:* rice: from 38 to 49 percent; wheat: from 26 to 40 percent; coarse cereals: from 19 to 29 percent; pulses: from 11 to 15 percent; fruits and vegetables: from 43 to 51 percent; food-grains: from 15 to 20 percent; oil-seeds: from 21 to 28 percent; sugarcane: from 29 to 46 percent. The proportions at 1991, when the food-crop production totals were substantially higher than in 1971, are not only higher than in 1971, they are also in all cases appreciable - and increasing. For *livestock*, smallholder farms (0 - 2.0 ha, aggregated) housed at 1991 about 60 percent of the national populations of cattle, of buffalo, and of sheep, and about 70 percent of goats and pigs.

1.4.2 Smallholdings and national food security

The foregoing percentage proportions for smallholder contributions to crop and livestock production thus highlight a very substantial, indeed vital, component in India's food-security system. Other rice-producing countries that have agricultural-land / agricultural-population ratio (Table 12, this document) comparable to that of India may similarly be benefiting from strong smallholder support to their food-security programmes. For the Philippines, an analysis by Bautista (1997, quoted in FAO 1998b Box C) concluded that had Government during 1965-1980 directed investment and subsidies to *smallholder* rather than to large-holding farms, poverty reduction and national economic growth would have been substantially greater than actually achieved. To the extent that this smallholder-dynamism feature is not already recognized in national food-security and poverty-alleviation strategies, Section 5 following suggests mechanisms and policies to maximize the production and benefits from smallholder agriculture.

[FAO's Medium-Term Plan (2000a) includes ongoing (and new and expanding) "regular" programmes, including Asia-Pacific-based food-security programmes and a rice-specific support strategy, wherewith to help governments strengthen the productivity and sustainability of smallholder farms and to enhance the livelihood of the smallholder families.]

In identifying mechanisms to maximize the production and benefits from smallholder agriculture, it shall be helpful to note that the fore-listed prominence of smallholdings in Indian crop productions and in livestock populations helps quantify the intensity of *crop-livestock synergies*. Such synergies shall be immensely helpful in enabling the rice-system farms and the associated rural enterprises to adapt to - and to benefit from - the opportunities and the necessities for producing at 2015 and 2030 the mix of agricultural products, many of high value, that shall be required by the populations' evolving numbers and diets.

Moreover - as emphasized by Steinfeld *et al* (1997) - smallholder crop-livestock integration provides to farm households the opportunities to intensify production, income, and assets, and to diversify risk; it also serves to promote biodiversity of soil micro-flora and micro-fauna.

Additionally, Kumar (Singh, Kumar, and Woodhead 2002) demonstrated that in India the farms larger than 1.0 ha (the "small", "medium", and "large" farms in aggregate) were, predictably, the source of the *marketable food-crop surplus:* whether of rice, wheat, coarse cereals, pulses, or oil-seeds. Expectedly, the sub-marginal-

size (< 0.5 ha) farms were not (in aggregate) able to generate any marketable food-crop surplus; nor, similarly were the marginal-size farms (0.5 - 1.0 ha). These (< 1.0 ha) households consequently required to *purchase* food to meet their nutritional needs. In Viet Nam's Red River Delta, however, farms of 0.25-ha average size do generate a marketable rice surplus (IFPRI 2000c).

These differing situations imply that differing rice-price *policies* would be appropriate within the national strategies that seek to lessen poverty: in India, *low* food prices, including rice price, would benefit these smallholder households; for smallholders in Viet Nam, *high* rice prices would be more beneficial. In both countries, the *rural landless poor* would benefit from low food prices. Rice-pricing and pro-poor policies in other rice-producing countries might similarly be guided by such considerations. Correspondingly, and following the fore-mentioned observations of Agarwal, Singh, and Swaminathan, the policy-oriented question may be posed: Is the developed-world concept of *minimal viable farm size* relevant and valid in *poor-country food-security-paramount rice-based agriculture?*

Experience of part-time rice farmers in Japan and RoKorea might suggest that it is not; as also does the observation that Asia's farm families derive much of their employment and their income from *non-farm activities*. However, Dixon *et al* (2001) suggest that in developing East Asia many farms are uneconomically small and that land aggregation should be facilitated. Moreover, there is clearly some minimal farm size below which current-type extension services, and perhaps other services also, could not expect to be cost-effective.

Another incisive conclusion from Kumar's (all-India) farm-size-effect analysis (Singh, Kumar, and Woodhead 2002) may also be relevant for other rice-growing countries. That analysis concluded that the smallholder farmers have been *equally as innovative* as larger-holding farmers in adopting technologies and in using purchased inputs, and more successful in increasing cropping intensity and in applying farm-yard manure to their lands. Such conclusions suggest that smallholders have adequate access, when needed, to *micro-financial services* - whether from formal or from informal sources.

Correspondingly, IFAD (2001 Box 3.4) synthesizes analyses for several Asian countries that indicate that productivity - on lands of comparable quality - was substantially higher on smaller than on larger farms. Additionally, and importantly for rural-enterprise development and rural-poverty alleviation (IFAD 2001), small farms employ more persons per hectare than do large farms, and smallholders and their employees spend more of their income on employment-intensive non-farm products.

1.5 Management of nutrients, tilth, water and pests

1.5.1 Nutrients management

For *nutrients* management - whether for individual crops or for sequences of crops - the required procedures, and their interactions with management of plant-population density, of water, and of pests, are well understood in general terms. Additionally, there are emergent methodologies and associated diagnostics to facilitate nutrients management, notably in irrigated-rice systems. These methodologies (described by Dobermann and Fairhurst 2000) include farmer-relevant assessments of indigenous nutrients-supply capacity, within-season nutrient dynamics, and regular replenishment of crop-depleted nutrient and micro-nutrient soil stocks.

Nutrients management is problematic for *rainfed* ricelands: except in very favourable rainfed-lowland environments, weather-related events and pest occurrences often constrain rainfed-crop growth, resulting in decreased or near-zero response to applied fertilizers. Moreover, the short-term (within-week) fluctuations in field-water status cause difficulty in the planning and in the execution of fertilizers applications. In the rainfed ricelands - and notably in the deepwater (floodprone/swampland) areas, fertilizer applications are understandably much less than in irrigated lands. However, technological and procedural developments during recent years are helping raise productivity in many of the less-constrained rainfed ricelands (IRRI-IFAD 2000), and fertilizer usage is increasing - albeit from a low base.

For both irrigated and rainfed lands, FAO (1998c, 2000a) has acknowledged expertise and experience, and ongoing programmes for documenting and promoting *integrated plant-nutrition systems* - in which manufactured ("mineral") fertilizers are used in combination with biologically-derived ("organic" - animal or plant) manures. Similarly, SARM methodology (FAO 1999b) comprises an integrated plant-nutrient

management - particularly but not exclusively in relation to *upland* systems. This management uses external inputs to augment the internal nutrient resources and processes, while ensuring minimal damage from external inputs and a maximal application of indigenous knowledge and practices.

Notwithstanding that manure alone - without any mineral-fertilizer augmentation, and without pesticides - can support low-level rice-system production, the consumer demand in Asia for (higher-cost) *"organically-produced" food* is likely to be constrained by the continuance of poverty and undernourishment. That poverty affects both the purchasing power of prospective buyers, and also creates highly-competitive alternative demands for the manure supplies. However, various Asian NGOs (Deccan Development Society, in FAO-NGO 2000) report some enthusiastic adoption of "organic-food systems" by some resource-poor farmers. Moreover, in some impoverished areas, rice-system production may perforce proceed without agrochemical inputs.

In all rice systems, impediments to the widespread adoption of efficient and environment-friendly nutrients management are the lack of field-visible responses to P and K fertilizers, and the continuing, often-subsidised, low cost of urea-N compared to P and K fertilizers. This notwithstanding the well documented benefits of P and K in conferring some measure of drought tolerance. Moreover, the current low cost of urea-N, and the cost of transporting the water contained in bulky manures, militate against intensive manuring of rice-system crops. "Environmental pricing" of urea-N -adapting policies from industrial-country agriculture - together with integrated plant-nutrient management might be an appropriate procedure for encouraging N-use efficiency in Asian rice systems.

It is here pertinent to emphasize IFAD's (2001) condemnation of misguided - though perhaps well-intentioned - attempts to promote low-inputs/high-output systems (whether for crops or for livestock): *if it were indeed possible to defy the laws of thermodynamics, farmers would long ago have done so, and there would have been no need of any Green Revolution.* However, as suggested in chapter 2.1.3, there may be niche-specific opportunities for low-input-cost/high-value-product systems.

1.5.2 Tillage and non-tillage

For land management, *no-till* and *reduced-till* systems may expect to be adopted increasingly for post-rice *non-rice* crops during 2002-2015. For post-rice irrigated wheat in the Indian and Pakistani Punjabs, no/decreased-till procedures - including *raised-bed* procedures - that use four-wheel-tractor-drawn seeders are finding favour with farmers (Rice-Wheat Consortium 2000a). Similarly, availability of mechanization may determine the extent to which decreased-till procedures are adopted for other post-rice crops. In which context IFAD (2001) expresses concern that decreased-tillage procedures shall lessen the demand for (often-impoverished) tillage labourers. For *rice,* no-till management may to some extent be adopted in Asian *upland-rice* systems - within integrative SARM procedures - and perhaps by 2020 in combination with perennial rice. *[The FAO (2000a) Land and Water Development Division has ongoing programmes for integrated land, water, and nutrient management in upland watersheds - including Asian watersheds.]*

For *submerged-soil rice,* no-till systems might not be adopted widely. However, there are likely to be trends towards dry-soil - rather than wet-soil - pre- and early-monsoon tillage to facilitate *dry seeding* of rice seeds. The motivation would be water economy. It is expected that the necessary cultivars and land-levelling and drainage techniques shall become more-widely available, and that associated weed, insect, and fungal-disease pests might in future be cost-effectively constrained. However, there are contrary reports (FAO 1999d, IRRI 2001a) as to the productivity of dry-seeding as compared to transplanting.

1.5.3 Rice-systems water

Agriculture - and particularly irrigated-rice cropping - is a dominant *user of water:* in developing countries it consumes about 75 percent of diverted water - and in Asia 84 percent (Facon, in FAO 2000c), of which about one-half for rice; in South-East Asia, rice comprises more than 90 percent of the irrigated-crop area. However, water per person in Asia (Guerra *et al* 1998, quoting Gleick 1993) declined by about one-half during 1955-1990, and is forecast to decline by one-third of its 1990 value during 1990-2025.

Thus, countries - globally numbering about 30 - having an annual internally-renewable freshwater availability of 1 000 to 1 600 m3 / person.ann are deemed *water-stressed* (IWMI 2000a: Global Water Scarcity Study).

Those of them (about 20) having less than 1000 m3/ person.ann are deemed *water-scarce:* for those 20, water *non*-availability is a severe constraint to socio-economic development and environmental quality.

At 2025, and in consequence of water being reallocated from agriculture to industrial, domestic, and environmental uses, Pakistan and parts of China and India shall be classified as "absolutely water-scarce". Parts of Pakistan's rice-wheat zone may already be water-scarce. In peri-urban areas of both Pakistan and Viet Nam (IWMI 2000b, FAO 2000a) domestic waste-water effluent is already used, without fertilizers, to irrigate high-value vegetables, but not rice. Additionally, rice-growing Cambodia, Malaysia, Myanmar, and Nepal shall require to invest substantially in water-resource development if they are to avoid water constraints; the costs of those investments may need to be recouped - in whole or in part - through increases in food and water prices (FAO 2000c). IFAD (2001) advises that rural-water charges are usually pro-poor, but that "safety nets" may be needed to ease the stress of initiating such charges.

Also pertinent to water resources and their development is the feature that globally - and including Asia's ricelands - about 1.5 B (billion) persons lack potable *drinking water* (IFPRI 1995c, UNICEF 2000). Of these 1.5 B persons, about 0.5 B reside in *rural* East Asia, and 0.2 B in *rural* South Asia (estimates derived from UNICEF 2000).

Correspondingly, 3.3 B persons lack *sanitation* - with adverse effects on associated drinking-water resources. Of these 3.3 B, about 1.0 B dwell in *rural* East Asia, and 0.8 B in *rural* South Asia (derived from UNICEF 2000). For Asia, the Asian Development Bank (ADB 2001c) estimates that poor sanitation and dirty water are the cause of 500 000 infant deaths per year, and also of much illness and disability. Globally, inadequate sanitation results each year in more than 1 B episodes of diarrhoea - inevitably impacting on human wellbeing, nourishment, educational achievement, and productivity. For South-East Asia alone, ADB (2001c) imputes to diarrhoea the deaths of more than one million persons in 1999.

There is legitimate concern that agricultural *water-distribution/allocation efficiency* is generally low - encouraged by policies of distorted incentives and prices. Globally, more than two-thirds of rice and wheat production currently derive from irrigated land. New sources of water, whether for agricultural or non-agricultural uses, are expensive to develop. Agricultural projections to Year 2030 presume small increases in irrigation availability - augmented by a water-pricing- and user-group- and technology-driven improvement in water-distribution/allocation efficiency.

[FAO's Medium-Term Plan (2000a) allocates appreciable resources to technical and policy aspects of water-use efficiency and water conservation - with substantial activity in Asian ricelands. Correspondingly, strengthening of on-farm water control is featured among the riceland activities of the FAO-facilitated Special Programme for Food Security.]

Similarly, technology is forecast to lessen the incidence and adverse effects of irrigation-induced riceland water-logging, salinization (Kijne *et al* 1998 prescribe ameliorative procedures - which can be labour-generating - IFAD 2001) and groundwater mining, and of water-supply pollution by agrochemicals. Though desirable for several reasons, the introduction of water pricing may result in food-price increases: there shall thus be need for ameliorative measures for the poor and vulnerable.

1.5.4 Pest and soil constraints

For rice-system *pests* and *adverse-soil-and-climate constraints,* food-production projections presume that technological (including cultivar) developments and procedures shall be able to contain, if not decrease, proportional crop losses to the current major pests and constraints. *Pest pressures* - particularly of weeds, and of pest-insects, and possibly of viruses and of stem/foliar pathogens, and of rats and birds and molluscs - may for rice and non-rice crops increase where rice-sequence cropping is annually repeated on the same land. [IRRI 1997 Chapter 6 lists in its Table 1 the most-damaging ricefield pests, and suggests that in most rice ecozones, and particularly in rainfed ecozones, weeding-labour constitutes a major production cost.]

For rice in *high-input* irrigated systems, there is proneness to lodging, and possibly a resistance to herbicides. In the *less-favourable* rainfed lowlands and in the deepwater floodprone / swampland areas, slow drainage of deep (and extensive) excess water shall continue to constitute a major (rice and non-rice) production constraint. However, technological and procedural developments are in some areas helping circumvent this

constraint - as in some rainfed ecozones of "water-depth classes" 0.0 - 0.3m and 0.3 - 1.0m where high-yield cool-season rice and imaginative cropping patterns are providing productive opportunities (IRRI-IFAD 2000).

For *wheat* in rice-wheat systems, the herbicide-tolerant weed *Phalaris minor,* and weather-induced seeding delay, and subsequent high temperatures during grain-filling, both result in decreased yield. Each of these wheat-yield-decreasing constraints can be countered by the *raised-bed* system of post-rice irrigated-wheat cultivation (Rice-Wheat Consortium 2000a, CIMMYT 2000a, Dixon *et al* 2001). This system gives benefit also of easier access for operations, together with savings of seeds, water, nitrogen, pesticides, and overall production costs. In all rice systems, *post-harvest crop losses* can be substantial - particularly for perishable commodities and for upland rice-system farms.

Procedures of *integrated (insect-) pest management* have been adopted to varying extents in several rice-system ecozones. This cultivar-and-information-and-training-based and livelihoods-oriented management has helped lessen insecticide-induced pest outbreaks and the development of insecticide resistance, and has also helped decrease production costs and operator-health dangers. Similarly, *weeds* and some *bacterial, fungal,* and *viral* diseases can now be managed more effectively than heretofore.

For *genetically modified* organisms (plant and animal), and for *biotechnological* pest management procedures, forecasts suggest that by 2030, if not earlier, the issues of human-nutritional and environmental safety shall have been resolved - probably to the benefit of developing world agriculture. *[The FAO (2000a) Medium-Term Plan includes a new priority inter-disciplinary activity to assist member countries on aspects of biosecurity.]*

The difficulties of quantifying crop losses to *pests* are highlighted in the observation of IFPRI (1998d, quoting Oerke *et al*) that responsible estimates for the losses - at 1988-90, for food and industrial crops, and to all pests - range from 10 percent to 50 percent of potential production. Globally, and for Asia, pathogens, insects, and weeds are estimated to each cause of the order of one-third of the total losses. For *rice,* IRRI (1997 Chapter 5 Table 3, quoting Evenson *et al*) suggests that the loss to all pests, aggregated for irrigated and rainfed systems, is about 20 percent of average yield; but, crucially the loss to climatic and soil constraints, both for irrigated and non-irrigated systems, is typically *three times larger* than the loss to pests.

The *lowland-soil constraints* in South and in East Asia include *salinity* - which affects 60 Mha of rice and non-rice lands, and for which tolerant cultivars provide an opportunity for agricultural utilization. Constraints also of *iron* toxicity (10 Mha), and of *high-organic* (peat) content (27 Mha); and in the Indo-Gangetic Plains of *sodicity / alkalinity,* for which reclamation may be accomplished (where cost-effective) through gypsum application in conjunction with appropriate water management. In *upland* rice-system soils the major (chemical) constraints are aluminium and manganese and iron toxicities, and phosphorus deficiency.

[FAO (2000a) has a regular programme - and facilitates an Asian network - on the amelioration and management of "problem" soils.]

1.6 Vision, goals and prospective interventions

1.6.1 Vision and goals

The **vision** for Asia's rice-based rural livelihood-support systems here envisaged is thus:

At Yr 2030, and throughout Asia's rice-dependent rural communities, all children (and their mothers) shall be adequately nourished and educated, all desirous adults, female and male, shall be gainfully employed, and all rice-dependent rural families shall reside in environs sufficiently attractive - physically and socially - to counter rural-urban migration, and with their farm resources and common properties managed sustainably and with sufficient resilience to survive calamities.

The corresponding *near-term* **goals** (for prospective FAO-assisted interventions) are:

At Year 2005, and in selected impoverished rice ecozones, specific technological and social ***interventions*** *to achieve the* ***vision*** *shall have been initiated by public, civil society, and private agencies in partnership with FAO and other UN agencies; the current adolescent generation shall perceive progress towards a brighter rural future.*

[Following sections introduce goals, objectives, and outputs for specific interventions.]

1.6.2 Objectives, interventions and procedures

In addressing the foregoing vision and goals, *FAO's objectives and mission* for support to prospective interventions during 2002-2006 for Asia's rice-based livelihood systems would derive from the strategies and thinking presented in FAO's (1999e) *Strategic Framework for Years 2000-2015,* in its *Medium-Term Plan* (FAO 2000a), in its (2000g, 2001a) proposed *Farming Systems Study for World-Bank Rural Development Strategy*, in its analyses of *Farming Systems and Poverty* (Dixon *et al* 2001) with its five strategies for improving farm-family livelihoods, and in its commitments within the *Special Programme for Food Security* (FAO 1999f), and within the *UNCED Agenda 21.* These objectives and mission would be consistent also with the inter-dependent strategies for five FAO Asia-Pacific region integrated *programme thrusts:*

- *Rice-based livelihood systems and their role in lessening hunger and rural poverty;*
- *Biotechnology, biosecurity and biodiversity: towards an evergreen revolution;*
- *Livestock intensification and enterprise;*
- *World Trade Organization: capacity building, multi-lateral trade, and an enabling policy environment;*
- *Disasters: early warning, prevention, preparedness and management.*

FAO's objectives and mission recognize that agriculture has almost always been the initial engine of wider economic development. However, agriculture has thereby frequently been subject to high taxation and distortive fiscal constraints. In consequence, growth in agriculture has in recent years lagged behind growth in total economies. Nonetheless, and following IFPRI's (1995a) paraphrasing of four items from FAO's 1945 Constitution, it is here emphasized that FAO-assisted rice-system programmes would seek to *promote agricultural growth* as a means to:

- *alleviate rural poverty;*
- *produce sufficient food and agricultural products to enable food security;*
- *contribute to national and global economic growth;*
- *conserve natural resources and improve rural environments - recognizing that over-exploitation of resources is a precursor of their destruction.*

In relation those fore-listed items, and recalling the aspects of rice-system water regime, it is here suggested that though all four of those items would be addressed by FAO-assisted interventions in both irrigated and in non-irrigated ricelands, interventions in *irrigated* systems would be particularly effective in addressing items (2) and (3), while interventions in the *rainfed* systems *(lowland, floodprone / swamp,* and *upland)* would have strong impact in relation to items (1) and (4).

The *broad* objectives for interventions to be assisted by FAO and partner agencies (national and international, and accessing pertinent comparative advantages) are in the following paragraphs summarized as *technological* objectives, *socio-economic* objectives, and *institutional and infrastructural* objectives. As with all FAO and UN-agency operations, assistance to particular interventions shall be provided only in response to member states' requests - which might expect, in part, to be "demand-driven" by the prospective beneficiaries. To facilitate such requests, it is appropriate that this present document should include a *"menu of packages"* for prospective interventions.

Such menu is presented in Section 5, where the indicative objectives for particular candidate interventions are reflected in those interventions' descriptive summaries. *[Specific* objectives for individual candidate interventions - and their expected outcomes / outputs - shall be prepared and published separately.] The menu includes innovative interventions of which farm families could not be expected to be aware, and thus not likely to be foreseen in village/district-level appraisals. It seeks also to take account of opportunities presented through national initiatives to *decentralize* rural development support, and of *lessons learned* through previous projects and programmes and their case studies - which can indeed be cautionary!

Candidate *technological* interventions would thus include objectives for assisting rice-system families (and particularly the resource-poor families) to avail of those primary-production and value-adding opportunities presented by:

- market-driven trends to supplant production of low-value staples by the production of higher-value food, feed, and oil crops, and livestock products - but recognizing poor families' continuing dependence on low-value staples;
- available and emerging technologies - nationally and internationally generated, and including germplasm - that can incorporate higher-value components within rice-based farming;
- available and adaptable procedures for rice-system management: including crop-nutrition, and water management - rainfed and irrigated - that balance requirements of sustainable resource use against those of resource conservation;
- existing incentive programmes for promoting agricultural biodiversity and carbon sequestration.

Candidate *socio-economic* ("wellbeing") livelihoods-oriented interventions - restricted to those for which FAO has expertise and advantage - would include objectives to assist governments to:

- strengthen micro-finance programmes - including informal programmes and urban-rural cash remittances;
- obtain for rice-system communities and enterprises an appropriate set of benefits and safety nets within the emerging patterns and protocols of international trade;
- prepare rural women (through education, information, resources) for their roles in lessening the numbers of low-birth-weight and undernourished children and in managing rice enterprises.

Candidate *institutional and infrastructural* interventions - restricted to those for which FAO, through its Sustainable Development Department, has comparative advantage - would include objectives for assisting governments at national and especially local levels to:

- implement reforms to the macro-framework that would promote rural interests - including rural social services, institutions, and infrastructures;
- ensure equitable access to resources of land, water, and common properties;
- lessen barriers - such as entry-permit requirements and costs, administrative / legal constraints, and lack of education and information - to co-operatives formation and to off-farm employment by smallholders and landless persons;
- upgrade transport, communications, and economic links to urban and peri-urban markets;
- construct market halls and storage buildings and start-up premises for value-adding enterprises;
- strengthen farm-water supplies.

Procedurally, the proposed interventions would target rural areas having high numbers of poor, undernourished, and vulnerable people. FAO would help locate such targets through the Food Inventory and Vulnerability Information and Mapping System (FIVIMS), with assistance perhaps from the Consultative Group to Assist the Poorest (CGAP). [Though Dixon *et al* (2001) caution that there is little data wherewith to identify poverty and hunger sub-nationally, M.S. Swaminathan (personal communi-cation 2002) advises that for India there shall in mid-2002 be state-aggregate data for poverty and for the relative sustainability of the underlying food-production systems.]

Operations, probably decentralized, and with a "livelihoods" orientation, would be focussed at village level, and would proceed in *partnership* with individual farmers and with *farmer and enterprise groups* - especially women-farmer and women-entrepreneur groups. As and where the target areas have farming systems similar to one of the generic farming systems identified by Dixon *et al* (2001), candidate interventions could be assessed in terms of one or more of the five types of poverty-reduction strategies enunciated by Dixon *et al* and previewed earlier:

- *Intensify* the existing production pattern;
- *Diversify* the system (with enhanced value-adding and market and product-quality orientations);
- Increase *farm size;*
- Augment *off-farm and non-farm income;*
- *Quit* farming - and migrate to a conurbation.

Wherever possible and appropriate, operations would be associated with the ongoing FAO-assisted *Special Programme for Food Security* (FAO 1999f) with its four components of endeavour, and with their overlap with the strategies of Dixon *et al:*

- Identify *constraints* to the enhancement of production and income;
- *Diversify* the farming-system enterprises;
- *Intensify* the production system;
- Strengthen the *water-management* mechanisms.

Additionally, operations could be supported also by the personnel and resources of the FAO initiative for *Priority Areas for Inter-disciplinary Action (PAIAs),*

[Already, some of the candidate interventions are providing a "test-bed" for the evolving methodology whereby PAIAs provide the technical and analytic ("normative" in FAO jargon) support to the SPFS "operational" interventions.]

It is thus pertinent to record here the notable success achieved by the SPFS (Special Programme for Food Security) in China. That programme commenced in 1995 in the south-westerly province of Sichuan: a province with appreciable areas of irrigated-rice systems - including rice-wheat systems. The programme was nationally formulated, with substantial participation of the intended beneficiaries, and with government support in the supervision of constructions / refurbishments and in the provision of micro-finance services. The programme has achieved several highly favourable impacts. There has been a substantial improvement in the condition of the natural and of the man-made (including irrigation) resources. There are self-sustaining procedures of micro-finance and of irrigation-system maintenance. Economic rates of return on interventions have been assessed, through internal and external reviews, as 14 - 20 percent. Farm-family incomes have increased appreciably - in large part, and with specific benefit to women - through the programme's *diversification component.* As a consequence of these impacts and experiences in Sichuan, the government of China has determined that for all provinces the Special-Programme methodology shall be an integral part of its policy to combat hunger and poverty.

In addition to their possible association with SPFS activities, the prospective interventions identified in later sections of this document could be accommodated also within appropriate "thematic groups" of the multi-UN-Agency Administrative Committee on Coordination, and its *Network on Rural Development and Food Security* and its *Sub-Committee on (Human) Nutrition.* They could simi-larly be accommodated within the broader mandates of the UN Development Group and of the UN Development Assistance Framework and the UN Joint Consultation Group on Policy. It is note-worthy that many of the concerned agencies, and several national and multi-national agencies, have representation in Bangkok, in close proximity to FAO's Regional Office for Asia and the Pacific. Noteworthy also that recent experiences indicate (Dixon *et al* 2001 World Bank 2001a) success with multi-stakeholder approaches to rural-livelihoods enhancement.

Interventions would necessarily proceed in collaboration with local agricultural-extension personnel, with Community-Based Organizations (CBOs), with NGOs and *Academia*, and with other appropriate agencies; they would expect to feature successful outcomes from recent and ongoing FAO rice-region programmes (including TCTTI, N-Efficiency for Rice, and FARM). Interventionist support would expect to operate for 3-5 years, though as is reasoned in FAO 1999b, SARM-type uplands-areas interventions require a longer time-scale, where-after the operational mechanisms - including any micro-finance and market-research/ information system should be self-sustaining.

[FAO (2000a), through the Rural Development Division of its Sustainable Development Department, has expertise and experience in designing institutional mechanisms to facilitate multi-stakeholder initiatives.]

2. Regional situations, trends and projections

2.1 Riceland areas and cropping systems

2.1.1 Rice area and water regime

Within their seven broadly-defined (FAO) agro-ecozones, rice systems can be further - and usefully - characterized and quantified (IRRI 1997) in terms of their *rice-phase water regimes:* Irrigated, Rainfed

Lowland, Floodprone / Swampland, and Rainfed Upland. The areal extent of each of these *major categories* of *regime* within each of the seven *AEZs* is depicted in matrix-*pictorial* format in Figure 2 of IRRI (1997, based on 1991 data); additionally, IRRI (1997) *tabulates* those areas of water regimes within individual *countries.*

Crucially - for the *marginal production* zones and their inhabitants and for the prospective interventions to assist them - the extensive South-Asian and South-East-Asian rainfed marginal regimes are analyzed and delineated in terms of *sub-categories, e.g.* "drought-and-submergence-prone", and "water-depth class", for which the constraints, vulnerability, and candidate interventions can be specified.

Table 5 (adapted from IRRI 1997) quantifies for all Asia, and for East Asia (both with and without China), and for South Asia (both with and without India), the harvest areas for each of the *major categories* of water regime - with double-cropped area counted twice, and all entries rounded to the nearest 1 Mha. Additionally, there are maps (Huke and Huke 1982, with electronic versions by Huke 1996) that delineate these major categories on a whole-Asia scale. Moreover, within the last decade - and facilitated by within-country geographic-information systems and personnel - detailed analyses and mappings at district and provincial level have been accomplished for the *sub-categories* of water regime. They are already guiding technological livelihoods-oriented interventions (e.g. IRRI-IFAD 2000).

For all water-regime categories in aggregate, Table 5 quantifies the dominance, in rice-area extent, of China in East Asia (which here includes South-East Asia), and of India in South Asia. Correspondingly, these two countries together produced at 1996/99 (FAO 2000b) about 60 percent of all Asian rice. At this continental scale, Table 5 indicates that Asia's harvested rice area totals about 133 Mha. Of this total area, the irrigated sector constitutes about 56 percent: it generates more than 75 percent of total rice production.

Nonetheless, high priority is now accorded (IFAD 2001, Dixon *et al* 2001, ADB 2000a, 2001b) to the rainfed lowland and to some deepwater areas by governments and civil societies in many of those countries in which the rainfed areas comprise an appreciable proportion of the total rice area. This priority is accorded in expectation of substantial investment returns in terms of enhanced livelihoods, production, national wealth, and sustainable resource management, and of lessened poverty per unit investment. Among major rice-producing countries, rainfed lowland and deepwater rice is proportionately extensive in Bangladesh, Cambodia, India, Laos, DPRKorea, Myanmar, Nepal, the Philippines, and Viet Nam.

2.1.2 Rice-based cropping systems

There are very many rice-based *farming* systems; within them, the various types of rice-based *cropping* systems (occupying the same field in the same farming year) comprise:

sequences: used in both irrigated and in non-irrigated systems: may include one, two, or occasionally three *rice* crops per farming year; after one or two rice crops, there may be grown one or more *non-rice* crops;

Table 5: Harvested area (million hectare, at 1991) for rice systems of various rice-phase water regimes

Region	Irrigated	Rainfed lowland	Floodprone/ swampland	Rainfed upland	Total
Asia	75	34	12	12	133
East Asia	50	16	4	5	75
East Asia exc PRoC	19	14	4	4	41
South Asia	25	18	8	7	58
South Asia exc India	5	5	3	1	14

[Source: Adapted from IRRI 1997; FAO (2000e) suggests a 1997 Asian-total rice-harvest area of 135 Mha.]

- *inter-croppings:* line-sown, used in all water-management regimes, but notably in rainfed-upland and in floodprone systems in both rice and non-rice phases, and often in the post-rice phase in irrigated and rainfed-lowland systems;
- *mixed croppings:* randomly-sown, used particularly in rainfed-lowland and rainfed-upland systems, and for both rice and post-rice phases;

- *relay croppings:* line- or randomly-sown, used in all water-management regimes, either/both at commencement and/or cessation of the monsoon; useful during receding-water phase in floodprone systems.

For individual fields, farms, and ecozones, choices among cropping-system options are determined predominantly by climate and by access to supple-mental water - whether irrigation-system or other, and to a lesser extent by soil constraints, farm-family needs, and by prices, costs, and available markets.

There are several rice-based *sequences*, variously incorporating one, two, or occasionally three rice crops per farming year. Correspondingly, after the initial rice, and in the same field in the same farming year, there may be grown one or more *non-rice* crops. In almost *all* rice-based sequences, the *timing* for the initial post-dry-season rice crop is constrained, even in irrigated ricelands, within the *monsoonal* rainfall period; or in deepwater systems, constrained to the months immediately preceding or following the monsoonal period. After that initial rice, and depending on water availability and farm-family constraints and opportunities, the rice-system farmers have many options for their second crop, and sometimes for a third crop, within the farming year. Occasionally, there are options also for multi-year rotations - perhaps including long-duration crops such as sugarcane. Thus, prevalent among the several sequences are:

Rice-Fallow-Fallow; *Rice-Wheat-Fallow;*
Rice-Maize-Fallow; *Rice-Legume-Fallow;*
Rice-Oilcrop-Wheat; *Rice-Groundnut-Fallow;*
Rice-Rice-Rice; *Rice-Rice-Wheat;*
Rice-Rice-Legume; *Rice-Rice-Oilcrop;*
Rice-Rice-Other; *Rice-Wheat-Rootcrop;*
Rice-Oilcrop-Sugarcane-Sugarcane-Wheat.

For farms lacking supplemental water, the options are usually restricted to the single-rice (rice-fallow-fallow) system, and to one or other of the two-phase sequences: e.g. rice followed by or relay-succeeded by a non-rice crop - or by an intercrop pairing - with a succeeding dry-season fallow. The three-crop or the multi-year sequences are more likely to be adopted by the irrigated or by the favourably-rainfed lowland farms. Disasters: Early warning, prevention, preparedness, and management.

A noted and successful crop-sequence adjustment within the last decade - and within the low-lying and hitherto impoverished deepwater areas of western Bangladesh and eastern India - has been the adoption of sequences that allow the deployment of appropriately-selected *"Boro"* rice cultivars and crop-management procedures (including "ratoon" procedures) to avail of the slowly-receding post-monsoon water. This recession occurs during the cooler cloudless-sky months when air temperature and crop respiration and pest pressures are low and solar irradiance and photosynthesis are high, such that yields also are high.

Additionally, in these lands, persistent shallow groundwater can be accessed for late-season supplementary watering using intermediate-technology low-lift water pumps - diesel-powered or treadle-operated. For pre- (rather than post-) monsoon operations, in flash-flood-prone resource-poor areas, a successful risk-avoidance strategy involves the pre-monsoon sowing of a combination, either *mixed* or *inter-cropped*, of two locally-suitable rice cultivars - one early-maturing, one late-maturing (IRRI-IFAD 2000). In other situations of less-intensive production, the simultaneous *mixed* or *inter-cropped* sowing of cultivar pairs differing by about 15 days in their growth durations can provide some risk avoidance and also some prolongation of the peak-load harvest and post-harvest operations.

From the many options for the crop immediately following the initial rice, *wheat* is almost invariably the preferred choice in ecozones and in price-support regimes that favour such rice-wheat sequencing - notably Central China and the Indo-Gangetic Plains. For areas not suited to rice-wheat, FAO (1997a: Bhuiyan) suggests that the farmers' next-preferred option, water permitting, is to grow a *second rice* crop. This preference reflects the farmers' competence to grow rice with comparatively low risk, their ability to store it within the household, the assured market with prices less volatile than for alternative crops, and relatively low production costs. More recently, FAO (2000c) cautions that - partly on considerations of price and profitability - a large proportion of newly-irrigated land is devoted to non-rice crops.

Nonetheless, rice-wheat cropping and rice-rice cropping, with or without a succeeding crop in the same farming year, are in many ecozones repetitively practised in the same fields year-after-year. They are essentially more *permanent* than other rice-based sequences. *Rice-wheat* sequences indeed have a long

history: there are written records for rice-wheat cropping in China about 1.4 millennia ago: Fei (1987) and Guo (1989). Conversely, *rice-rice* sequences are essentially a modern outcome of the availability of irrigation and short-duration cultivars.

2.1.3 Cropping systems: locations and areal extents

Because of its relative permanence, it is possible to make analyses and to generate statistics for rice-wheat as a *system.* Through computerized-mapping analyses, it was reliably estimated (Woodhead, Huke, and Huke, 1994) that at 1989/90 the total area of rice-wheat repetitive cropping was about 21 Mha: comprising 0.5 Mha in Bangladesh, 9.1 Mha in China, 9.5 Mha in India, 0.4 Mha in Nepal, and 1.4 Mha in Pakistan. That total may at Year 2002 have increased to 25 Mha: comparable to the estimate (FAO 2000c) that rice-rice and rice-rice-rice sequences might in aggregate at 1999 have occupied 28 Mha of riceland. The *cultivated areas* of the corresponding "generic" farming systems of Dixon *et al* (2001) are 62 Mha for rice-wheat systems (South Asia only, East Asia not specified) and 93 Mha for rice-rice systems (East Asia and South Asia combined).

For rice-wheat cropping in Bangladesh, China, India, Nepal and Pakistan, national and regional atlases - based on district-level computer-mapping analyses - have for each country been published for the areas and locations of the rice-wheat systems and for the time-trends in their per-person contributions of grains and of calories for food security and for human nutrition (Huke, Huke, Woodhead, and Jikun Huang, 1993; Huke, Huke, and Woodhead, 1993a and 1993b; Woodhead, Huke, and Huke, 1993; Woodhead, Huke, Huke, and Balababa 1994).

However, in those rice-growing areas that are not suited to rice-wheat nor to rice-rice sequences, no single (non-wheat, non-rice) post-rice crop exercises a dominance comparable to that of wheat and the second rice in their respective zones. Nor can the locations nor the areal extents of such sequences be specified so readily as for the rice-wheat and rice-rice sequences. Nonetheless, useful indicators for the locations for several widely-adopted sequences have been compiled for China and for India, which together contribute almost 60 percent of the Asian rice-growing area, and for some few other rice-growing countries.

For *China,* Wang and Guo (1994) and FAO (2000c, Zhu, using 1988 data) describe and quantify the north-south climate-determined *zoning* of various prevalent cropping sequences. Expectedly, the regions of double- and triple-cropping of rice are located in the more-southerly provinces, including the central-eastern provinces. Adapting from Wang and Guo (1994) and from Huke *et al* (1993), the approximate *land* (as distinct from harvest) *areas* of rice-based sequences at 1990 are estimated as: rice-fallow 3.8 Mha, rice-wheat 9.8 Mha (including 0.9 Mha of rice-rice-wheat), rice-oilseed 4.5 Mha (including 2.9 Mha of rice-rice-oilseed), rice-rice-greenmanure 3.9 Mha, and rice-other 0.6 Mha.

For *India,* a review by the Cropping Systems Directorate (1997) lists for both irrigated and rainfed systems the thirty most-common crop sequences, whether with or without rice, in each of twenty agro-ecological regions. Among those thirty sequences, seventeen include rice, and of those seventeen, six have sufficient areal extent that they can be por-trayed on a national-scale map. The six sequences are rice-rice, rice-wheat, rice-pulse, rice-oilseed, rice-groundnut, and rice-sorghum. In terms of the numbers of administrative districts for which a particular sequence is among the district's four most popular sequences, the three first-ranked sequences (all India) are rice-wheat, rice-rice, and rice-oilseed.

For *rice-rice cropping* in India - predominantly in southern and north-eastern states - the area is currently (Siddiq 2000, and in FAO 2000c) about 3.4 Mha (7 percent of the total rice area), having been somewhat higher during 1960-80. In irrigated rice-rice areas in southern India, the second rice may be followed by a pulse, an oilseed, a sweet-potato, or a third-rice crop. *Rice-maize* and *rice-oilseed,* irrigated or rainfed, are featured in north-eastern Indian states (V. Pal Singh, personal communication, 2000).

Rice-fallow-jute is practised in *Bangladesh,* and rice-wheat-maize and rice-potato-maize in *Nepal.* In *Sri-Lankan* rice-based sequences - stratified approxi-mately in relation to land elevation and irrigation / drainage patterns, and with some rice-rice cropping in southern districts - the dominant post-rice crops are chilli, onion, and groundnut (FAO 2001g).

Among South-East Asian countries, rice-rice cropping, and occasionally rice-rice-rice cropping, is widely practised in Indonesia, Myanmar, the Philippines, and Viet Nam. The dominant post-rice crops are maize, garlic, and tobacco in the *Philippines*, and soybean, mungbean, and peanut in *Thailand*. In *Viet Nam,* rice-rice

is followed by potato, vegetable, or maize in the Red River system, and by peanut, groundnut, or soybean in the Mekong system (FAO 2001g).

[FAO (2001g: Duwayri) has a specific programme entity "Alternative crops and cultivars for new opportunities" that seeks to make available to farmers the cultivars and knowledge wherewith to pursue niche-specific options in high-value lesser-used crops to produce food (including herbs, spices, and colorants), feed, fibre, fuel, and pharmacia. This programme entity would be supportive of the interventions proposed in this document.]

For Asian developing rice-growing countries as a whole, the total areas (1996/99 averages, FAO 2000b) of *wheat, maize,* and *pulses* are 72, 42, and 33 Mha. The estimated area of rice-wheat cropping (21-25 Mha) is thus considerably less than the total area of wheat. It may correspondingly be asserted that the areas of *rice-maize* and of *rice-pulse* systems are respectively substantially less than 42 and 33 Mha. IRRI (1997, Appendix-Table 2, 1991 data) lists for seven rice-growing *AEZs,* and by *country* within those AEZs, the areas occupied by rice, by wheat, by maize, and by other grains. It lists also - for rice - the areal extent of the four categories of rice-phase water regime.

2.1.4 Fish and livestock components

Within the rice-based *farming* systems, there is a small but locally valuable contribution of protein, vitamins, and income from quickly-maturing *fish.* Such fish (finfish, but also crabs and shrimps in coastal China - Dixon *et al* 2001) are usually raised during the rice phase of the farming year, either in ponds or in the ricefields, with fish-refuge areas excavated within the rice field to permit fish survival during water-shortage periods and to facilitate the fish harvest. Alternatively, in some enterprises for which the fish production is a dominant source of the annual farm income, sequences such as rice-fish-rice-fish are practised.

Livestock - and particularly *dairy cattle, small ruminants,* and *poultry,* and their products - are assuming dietary and economic and environmental importance - the "livestock revolution" - in several rice-growing ecozones and countries. Significantly, at 1995/97, *livestock products* constituted about 40 percent of the gross global value of all agricultural production; and the ratio of developing / whole-world value for livestock products shall increase during 1996-2015 from 51 to 63 percent for meat products and from 36 to 54 percent for milk products. Poultry's share of global meat trade increased from 13 to 28 percent during 1965-1995.

Thus in China, the value of livestock-products GDP as a proportion of all-agriculture GDP increased from 15 percent in 1978 to 30 percent in 1996. For India, corresponding proportions were 17 percent in 1981 and 27 percent in 1999. Moreover, analyses for all-India (Singh, Kumar, and Woodhead 2002) indicate that during recent years the growth rate in total factor productivity for *livestock* - at 1.8 % / ann - has exceeded that for *crops* (1.0 % / ann).

At the household level: for rice-wheat and rice-wheat-mustard farming in the unfavourable areas of Eastern Uttar Pradesh (India), livestock contributes 20 to 30 percent of household income, with a further 50 percent (IRRI 2001a) from non-farm activities. Throughout the rice-based systems, ruminants, particularly, can for smallholder households constitute sources of savings, income, meat, milk, hides, fibre, horn, manure and draught power (Dixon *et al* 2001, FAO 1999c). The rice systems may house about 200 million bovine livestock, and somewhat fewer smaller ruminants.

Growth rates in production per person of total *meat* and of *milk,* though each imprecisely determined, have generally been considerably higher than rates of human-population increase. In Asia, though less so in Southern America and Africa, *feed* and *fodder* for livestock is increasingly supplied in feedlot and stall systems by *coarse grains, oil-meal* products, and sometimes sweet sorghum; proportionately less feed derives from pasture land and grazing land. However, in some ecozones, and notably in East Asia, there may be insufficient ruminant-feed supplies to support a major expansion of livestock populations (Dixon *et al* 2001, FAO 1999c).

Nonetheless, forecast average growth rates (1996-2030) for *dairy-cattle populations* are 1.4 % / ann in East Asia and 2.2 % / ann in South Asia; and for *poultry populations* 1.3 % / ann in East Asia and 2.8 % / ann in South Asia. Rates are lower in East than in South Asia as a consequence of the already-high food availability in China. The South and East Asia regions have similar forecasts for growth rates in *pig* populations (each 0.9 % / ann), and in *sheep-plus-goat* populations (1.3 % / ann).

The projected increases in livestock numbers have several implications: technological, environmental, and socio-economic (see Section 5) for rice-system farms and their families. Among these implications are that livestock activity shall become a larger component of the farm enterprise, and shall (FAO 1999c, 2000c) increase substantially the per-person requirement for water for food and feed; maize and oilseed crops shall feature more strongly in the cropping systems - perhaps displacing some rice; livestock wastes, including liquids and ammonia and greenhouse gases, shall require environment-friendly management (LEAD 1999); and there may be displacement of families whose existing (extensive) livestock enterprises may be rendered uncompetitive.

[However, as with rice so also with livestock, FAO (2001c) reports a global over-supply of livestock and of meat products and a sharp decline in prices during 1998-2000. Worryingly, there is indication also (FAO 2001c) that annual global assistance to the livestock sectors in developing countries declined from about US$ 330 M in 1996 to about US$160 M in 1997 and 1998 and to only US$80 M in 1999; the livestock share of multilateral assistance to agriculture thus declined from about 3 percent in 1996 to only 1 percent in 1999.

FAO's technical assistance (Medium-Term Plan 2000a) to Livestock and Poverty Alleviation, to Livestock Health and Hygiene, and to its Livestock Environmental and Development Initiative, thus have heightened importance. This lessening of global assistance to livestock is, however, and regrettably, a manifestation (FAO 2001d, Singh 2001b, and others) of a general substantial decline in global assistance - including Development-Bank assistance - to all components of developing-world agriculture during the decade 1987/89 to 1997/99.]

2.1.5 Implications for interventions

The large areal extent (about 25 Mha) of the *rice-wheat systems* justifies an in-depth review of those systems and the lessons that they can provide. The major expansion of those systems post-1960 resulted from the triple-conjunction of new short-duration photoperiod-insensitive cultivars for both rice and wheat, of sufficient affordable fertilizer to complement the new cultivars' fertilizer responsiveness, and of more-widespread irrigation facilities. Additionally, the synergism among those three features was beneficial (Singh and Paroda, 1994). Corresponding synergisms - which may similarly be beneficial in promoting increased agricultural production and human wellbeing - must be recognized and utilised in other production systems during the initial decades of the new millennium.

240. These several fore-mentioned categories of rice-based production systems expectedly feature in FAO's (2000g, 2001a, and Dixon *et al* 2001) considerations of the strategies and methods by which interventions in several broadly-defined and extensive regional livelihood-supporting farming systems can be assisted to increase production and income and to lessen poverty. These broadly-defined farming systems have some congruence with the water-regime categories (irrigated, rainfed lowland, rainfed upland) which were introduced earlier. They are therefore here presented (in Box 1 - abstracted from FAO 2000g: *Proposed Farming Systems Study for World- Bank Rural-Development Strategy* and FAO 2001a: *Global Farming Systems Study: Challenges and Priorities to 2030)* as an indication of the extent to which appropriately-targeted interventions might within a livelihoods approach - contribute to the lessening of rural poverty.

2.2 Human populations, food security, employment and undernourishment

2.2.1 Nourished and undernourished populations

Projections (FAO 2000d) to Years 2015 and 2030 for (global and regional) human populations and for the numbers of undernourished and of adequately-nourished persons are summarized in Table 6. For both East Asia (including South-East Asia) and for South Asia, the encouraging message from these realistic projections is that the global food-production systems (including their rice-based components) should be able to ensure that in East Asia at Year 2015 there shall be 1.99 B persons adequately nourished (and at 2030, 2.22 B) compared to 1.56 B at 1995/97 - at which time similarly there was a substantial increase compared to the 1.01 B at1979/81. For South Asia, the corresponding totals were/are 0.56 B adequately-nourished persons at 1979/81, 0.97 B at 1995/97, 1.48 B at 2015, and 1.84 B at 2030.

Table 6: Human populations and their state of nourishment (each in billions of persons) : 1996-2030

Grouping Date	1995/97	2015	2030

	Total	Adequately nourished	Under-nourished	Total	Adequately nourished	Under-nourished	Total	Adequately nourished	Under-nourished
World	5.75			7.15			8.10		
Developing countries	4.43	3.64	0.79	5.77	5.19	0.58	6.71	6.31	0.40
East Asia	1.80	1.56	0.24	2.13	1.99	0.14	2.31	2.22	0.09
South Asia	1.25	0.97	0.28	1.65	1.48	0.17	1.92	1.84	0.08

[Source: FAO 2000d.]

However, notwithstanding these encouraging aspects, Table 6 indicates that in East Asia at Year 2015 the *number* of *undernourished* persons (144 million) shall still exceed one-half of the 1995/97 total (240 M); for South Asia, correspondingly, 165 million at 2015, compared to 284 M at 1995/97. Only by 2030 shall the numbers of undernourished in each of these regions be appreciably fewer than 100 million. Moreover, this persistence of undernourishment is a manifestation of *lack of purchasing power* wherewith to buy food, rather than a shortfall in food production. The need to create income-generating opportunities for the poorest rice-system smallholders is thus vital.

Average-annual *human-population growth rates* corresponding to the totals in Table 6 are for East Asia 0.9% / ann during 1996-2015 and 0.5% / ann during 2015-2030; South-Asia figures are 1.5% / ann and 1.0% / ann. However, these regional-aggregate figures conceal substantial differences among constituent countries. Thus in South Asia (FAO 2000b), the 1996-2010 projected growth rates of 1.5% / ann in Bangladesh and of 1.3 % / ann in India contrast with 2.1 % / ann in Nepal and 2.3 % / ann in Pakistan. These differences have consequence for the relative persistence (among countries) of food insecurity and of poverty.

Box 1: Characteristics and potentials of farming systems in Asian regions

Region / Farming system	Land area (% of region)	Ag. Pop'n (% of Region)	Principal livelihood	Incidence of poverty	Potential for poverty reduction	Potential for agric. growth
East and South-East Asia						
Lowland rice	12	44	Rice, maize, pulses, sugarcane, oilseeds, vegetables, livestock, aquaculture	Extensive severe poverty	Moderate	Moderate
Upland intensive mixed	20	28	Rice, pulses, maize, sugarcane, oil seeds, fruits, vegetables, livestock	Extensive moderate and severe poverty	Moderate	Moderate
Highland extensive mixed	6	4	Upland rice, pulses, maize, oil seeds, fruits, forest products, livestock	Moderate to severe poverty	Moderate	Moderate
South Asia						
Rice-rice	7	17	Rice (two seasons), vegetables, legumes, off-farm activities	Extensive severe poverty	Moderate	Moderate
Rice-wheat	19	33	Rice, wheat, vegetables, livestock including diary, off-farm activities	Extensive, moderate, and severe poverty	High	Moderate-high
Highland mixed	13	7	Cereals, livestock, horticulture, seasonal migration	Moderate to severe poverty	Moderate	Moderate

Rainfed mixed	29	30	Cereals, legumes, fodder crops, livestock, off-farm activities	Extensive poverty; severity varies seasonally	Moderate	Moderate

Sources: FAO: Proposed Farming Systems Study for World-Bank Rural-Development Strategy; (Weatherhogg, Dixon and de Alwis, 2001; and Ivory, 2001)

2.2.2 Creating rural employment

Crucially, within the table 6 population totals there is detail of immense significance. In much of the developing world, including East Asia and South Asia, and as a consequence of the age distribution, there is an ongoing and rapid rise, to continue to Year-2020 or thereabouts, in the ratio of prospective workers (and savers) to dependants. This constitutes a *"window of opportunity"* or *"demographic gift"* to lessen poverty and undernourishment. But it constitutes an opportunity only if appropriate policies enable the prospective workers to find employment.

Much of the required employment can and should be in rural areas; some of it perhaps directed to activities (on lands with assured tenure, Dixon *et al* 2001) such as tree planting and the installation of field drains and fish ponds, and much of it to rurally-based value-adding agroprocessing enterprises. Rural-employment opportunities must accommodate the feature that many of the prospective workers shall be computer- and informatics-literate. For either category of prospective employee, and as FAO (2000f) reports, the investment-plus-recurrent *cost for a rural workplace* is substantially *less than* for an *urban workplace.* In most developing economies such rural-employment generation is agriculture-driven - whether on-farm, off-farm, or non-farm. There shall be need for substantial investment (ADB 2001a) - but there are guiding models for such investment programmes.

One such (highly successful) programme is the Township and Village Enterprise (TVE) Programme in China (FAO 1998b Annex 3). Between 1970 and 1996, that programme created employment for about 100 M (million) rural labourers - 20 M of whom in construction activities, and 80 M in industry - often as sub-contractors to urban industries: consumer goods, textiles, construction materials, farm machinery, and food processing. It thereby facilitated, in combination with some rural-urban migration, a substantial decrease in the proportion of rural labourers engaged in agriculture. TVEs, in aggregate, generated at 1996 about three-fourths of the *rural* gross output value and about four-tenths of *national* export earnings.

For other Asian countries wishing to develop similar rural-employment-generating programmes, FAO (2000a) has the mandate, expertise, ongoing programmes, and an *Investment Centre* wherewith to provide technical support and to assist member governments to obtain external funds to help finance the necessary investments, and to help national agencies to identify and to lessen any barriers - such as entry-permit requirements and costs, and lack of relevant education - to rural off-farm employment.

At *household* scale within the rice-based communities, post-harvest value-adding activities provide on-farm and off-farm opportunities for creation of new employment, and for expansion of existing employment, and correspondingly for income augmentation. It is thus helpful that, as the world's largest industry, the food industry has the capacity to accommodate an enlarged workforce. Employment-creation opportunities for the ricelands derive from the crops and from the livestock phases, and possibly from the fish phase, in mixed rice-based farm systems.

For *rice*, there are many established and emerging options for *food-products* manufacture - at household, community / co-operative, and small-industry scale. The options are in part determined by the rice-grain amylose content (AC), and are thereby likely to be country/ecozone-specific. The many options are featured, and their processing described, in FAO (1997b). They include desserts, cakes, crackers, and sauces (using lowest-AC grain); baby foods and breakfast cereals - popped, puffed, or flaked (low-AC); soups, crackling, and fermented cake (intermediate AC); and noodles (high AC).

Additionally, rice may be processed into flours, starches, batters, and thickeners, into pre-cooked or quick-cooking convenience foods, and into syrups, wines, and spirits. Some of these rice products provide the option to incorporate other rice-system products - such as pulses, coconut, or dried fish; if of high quality, such products have export potential. *Brown rice*, with the option for pre-milling pressurized moisture-conditioning

that permits higher recovery of vitamins, minerals, and proteins, is likely to become increasingly marketable as populations become more health-conscious.

FAO (1997c) has reviewed also the value-adding and employment-generating possibilities from the four main rice *by-products: broken rice, bran, straw,* and *hull*. Expectedly, *broken rice* may be used similarly to non-broken milled rice - as in flours, starches, syrups, beers, wines, and spirits; it is used also as a poultry feed.

For rice *bran,* and despite its high free-fatty-acid content and its proneness to contamination during milling, there are many options for products and processing - including health-enhancing dietary-fibre foods and products that can lower blood cholesterol in humans. Bran may be used also as a feed supplement for sheep and pigs, and in the manufacture of wax and cooking oil.

Rice *straw* has many potential and proven uses, but for many of them there are more-convenient alternatives, and straw remains under-utilized and often burnt. Within rice communities, some straw is used (sometimes with rice bran) as mushroom bedding, and some is rendered palatable to livestock through treatment with urea or/and appropriate micro-biological inoculants.

Rice *hull* (or husk) is, like straw, much produced and little used. There is some minor usage as sheep-feed supplement, and as a composting and seed-bed ingredient; and some industrial use in the production of ceramics, fibre-board, and silica. There are proven technologies and prototypes to use rice hull as a fuel - either in direct combustion (briquette), or by gasification (FAO 1991) to produce a fuel for internal combustion engines that generate electricity. This document review other bio-fuel options for rice-system communities, and the possibilities to avail of Agenda-21 / Kyoto-Protocol provisions.

Rice-system *livestock* similarly provide on-farm and off-farm value-adding and employment-creation opportunities - both at community / co-operative and at small-township scale, and particularly for women (FAO 1999c). Poultry, cattle, and pigs perhaps offer most opportunity to smallholder rice farms. For each of them, individual farms may expect to compete effectively in village markets, but groups / co-operatives, with agro-economic marketing support, shall be needed to penetrate urban markets and export markets.

For *poultry,* and whether for meat or for eggs, native chicken and hybrid duck may provide worthwhile income-generating options. Noting that rice bran may provide much of the supplemental (non-scavenged) feed for rice-system poultry, then slaughter-house blood meal may provide an additional and low-cost and market-acceptable poultry-feed ingredient. Whatever the feed, hybrid duck can expect to be more productive than indigenous duck, and to provide additional protein and income to farm families; there are reliable sources for the required exotic males. Hybrid-duck meat, when processed with suitable spices and non-meat ingredients, can supply low-cost protein to rural communities and to their school-lunch services.

For both chicken and duck, appropriate-technology small-town slaughter-and-dressing systems and blood-meal-manufacturing systems are available - with supportive advice / expertise; as also is advice and training for artificial insemination and for housing, hygiene, and health. .

For *cattle,* rice farms smaller than 0.4 ha may provide insufficient land and feed resources. There are, however, prototype systems of communal housing and management - but with individual livestock ownership - wherewith smallholders can participate in beef or dairy production and income generation. However, such participation generally requires medium-term micro-finance support - both for the individual owner and for the communal enterprise. The construction cost for a 50-animal house is typically $1 500. Helpfully, suitable cross-bred stock are available that can be fattened or milked when fed on diets incorporating appreciable proportions of processed rice-straw and a little rice-bran. For indigenous breeds and smallholdings, FAO (1999c, Figure 15) emphasizes that relatively small quality-feed supplements can impact strongly in enabling livestock to transform from a maintenance-metabolism existence to one of profitable production.

For indigenous and for cross-bred cattle, procedures of hygiene and health, particularly for parasites, are well known, but resources may be needed to ensure their application. Lacking such application, production and income may be constrained, and access to supermarkets and other quality outlets debarred (as also for poultry). For beef-cattle processing, designs are available for small-town abattoirs, and there are various programmes of training for meat inspection and for meat-processing technologies. For smallholder milk producers, technologies are available to delay milk deterioration while awaiting collection and during transport: technologies both of preservation by lactoperoxidase, and of farm-scale packaging-with-pasteurization.

For South-East Asia, and as an alternative to beef-cattle raising, *swamp-buffalo* enterprises may provide a less-risky income-generating opportunity. Such buffalo are better feed-converters than cattle, can make use of low-quality feeds, and are more resistant to ticks and tick-borne diseases. Moreover, at comparable age, buffalo meat and beef are equally acceptable to most consumers.

[FAO (2000a) through its Agricultural Support Systems Division and its Animal Production and Health Division has expertise and mandate to assist member countries to identify and pursue post-production and agro-industry employment-generating opportunities.]

2.2.3 Effects of 1997-98 economic crises

For both rural and urban poor in South-East and North-East Asia, the 1997-98 *economic crises* impacted seriously - and may in 2002 continue to impact - on the numbers of poor and on their food insecurity. IFPRI (1998b) and FAO (2001d) report that the return of urban newly-unemployed to their home villages in 1997-98 caused a decrease in agricultural wages and an increase in rural unemployment - particularly of rural women.

The numbers of *rural undernourished* increased substantially in Indonesia and the Philippines. Cost of food imports into Malaysia doubled - from US$ 4B / ann to US$ 8B / ann. FAO (1999a and 2001d, quoting World Bank) reported - for 1998 as compared to 1996-97 - a doubling of poverty in Indonesia and RoKorea (urban in the case of RoKorea), and in Thailand a 13 percent increase. Thus for South-East Asia (alone) the crisis caused (ADB 2000a) an increase of 10 million in the number of poor persons. In *standard of living*, Thailand experienced a 14 percent decline; and Indonesia suffered a 24 percent decline, such that consumption of milk, eggs, and vitamin-fortified foods decreased, with consequent increases of night blindness in women and of anaemia in children.

Moreover, IFPRI (1998b) and ADB (2001a) posed the question: shall Year-2020 nutrition / poverty projections be distorted if the crisis effects continue? Such continuance was perhaps manifest in 1999 in Indonesia (2000, Statistical Year Book 1999), where the proportion of the population classified as *"below poverty line"* was determined to be about 23 percent - twice its pre-crisis value, though less than the 1998 peak; proportions are increasingly higher in rural areas as compared to urban areas - the urban areas benefited proportionately more from decreased prices of essential commodities. These impoverished rural areas include many of Indonesia's major rice-producing zones.

Additionally, for Indonesia, RoKorea, and Thailand, FAO (2000b) reported (for 1999) signifi-cant decreases, as compared to 1997, in food-production indices and in livestock-production indices. However, and encouragingly, FAO (2001d) suggests that governments' remedial measures were effective, and the economic recovery has, excepting Indonesia, been faster than expected - though econo-mic growth has still been slower (ADB 2000b) than would have occurred in the absence of the crisis.

Regrettably, and in several developing countries, there shall be severe sets-back to these recoveries, and to rural-poor communities and their children and other vulnerable groups, as a consequence of the terrorism of 11 September 2001.

2.2.4 Forecasts for food requirements

From the projected human-population totals for Years 2015 and 2030, forecasts have been made for the likely *production requirements* for rice and for other *food* crops (corresponding growth-rate require-ments were summarized in Table 3). Forecasts (FAO 2000d) for *all developing countries* (but essentially Asian countries for rice) for *food*-crops annual pro-ductions required at 2030 (with values at 1995/97) are: *rice* 765 (540) Mt / ann; *wheat* 420 (270) Mt / ann; *maize* 505 (255) Mt / ann; and *soybean* 155 (65) Mt / ann. These forecasts recognize the considerable diversity (among rice-producing countries) in dietary preferences for *rice:* indeed, the proportion of calorie requirement that is met by rice ranges from 5 percent in Pakistan to more than 70 percent in Bangladesh, Cambodia, Myanmar, and Viet Nam.

For *South Asia* in aggregate, Paroda and Kumar (2000) estimate that at Year 2030 - with a predicted South-Asia population of 1.92 B, and a continuing dominance of food grains (60 to 70 percent of calories in the national diets) - the combined *food*-grains require-ment *in the household* shall be 320 Mt / ann, comp-rising 145 Mt / ann of rice, 112 Mt / ann of wheat, 14 Mt / ann of maize, 23 Mt / ann other coarse grains, and 25 Mt / ann of pulses. Additional requirements (in aggregate about 45 Mt / ann) - for livestock *feed,* for seeds, for industrial

use, and for wastage - raise the total to 365 Mt / ann. Rice and wheat each contribute about 15 Mt / ann to that additional need.

2.2.5 Indications of food supply from rice systems

For India alone, IFPRI (1999b) suggests that there might at Year 2020 be a deficit in all-cereals production of about 50 Mt / ann. However, as suggested in this document's table 3, the more-recent FAO 2000d analysis indicates that for most food crops (including cereals), and globally and for East Asia and South Asia, the annual growth rates in production that shall be required during 1996-2030 are substantially less than those that were achieved during 1967-96. Thus for *rice*, globally, and here elaborating the Table-3 data, the annual growth rate in production during 1975-95 was 2.3% / ann : the required rates during 1995-2015 and 2015-2030 are respectively forecast as only 1.2% / ann and 0.6% / ann. However, for rice for India, chapter 1.2.3 cautions that yield-growth rate may during 2002-2004 fall below the population-growth rate.

Among specific rice-based cropping sequences, the *rice-wheat sequence* is one for which detailed district-level analyses have been made of the proportion of preferred calorie requirement that can be satisfied by local production of rice and wheat (Rice-Wheat Atlases for Bangladesh, China, India, Nepal, and Pakistan, by Huke, Woodhead, and co-workers, 1993 and 1994). Thus, using FAO (1990) specifications for calorie requirements, and with adjustments for effects of climate, average weight per person, national dietary preferences, and losses of production to wastage and pests, values were calculated for the annual per person production of rough-rice-plus-unmilled-wheat needed to satisfy the milled-rice-plus-wheat-flour component of the national-average per person nutritional requirement.

The resultant estimates were 300 kg / person.ann for Bangladesh, 200 kg / person.ann for China, India and Nepal, and 150 kg / person.ann for Pakistan. The Rice-Wheat Atlases quantify the general and impressive success of the rice-wheat-system districts in increasing rice and wheat production during 1950-1990 sufficiently not only to meet the nutritional requirements of the substantially-increased local populations but also to generate surpluses for export to other provinces and states and for input to the food-security buffer stocks.

2.3 Economic growth and rural wellbeing

2.3.1 Economic growth: influences and forecasts

Economic growth in the general economies, including their agricultural economies, and *population growth* have in the past determined, and shall in the future determine, the aggregate and the sectoral growth in agricultural products and enterprises. Responsible global projections for *future trends* in areas and yields for crops, for livestock, and for fisheries, and allowing for the projected availability of inputs, shall indicate the extent to which agricultural systems - including rice-based systems and their import / export capabilities - shall succeed in meeting the projected demands for food and for food security.

Precise forecasts for economic growth are a crucially important component in any food-security-projection undertaking. Unfortunately, precision in such forecasts is difficult to achieve - even for industrialized economies and for their near term. For developing Asian countries, FAO (1998b, citing various sources) suggests that a robust forecaster of economic growth is the population's access to education, nutrition, health, and land (and thereby credit) - leading in turn to enhanced wellbeing and higher and more-equitably distributed incomes.

However, the difficulty in attaining precision in developing-country income-growth forecasts may be indicated by IFPRI's (1999b) experience in attempting to predict trends to Year 2020 in the income / person in India: responsible estimates can be as high 6% / ann or as low as 2% / ann. The implications are vital: thus, for South Asia in aggregate, IFPRI (1998a) calculates that with 5.5 % / ann economic growth to Year 2020, the number of undernourished children (which was 86 M at 1995/97) shall decrease to 66 M. However, with 4.0 % / ann economic growth, undernourishment and poverty shall not by Year 2020 have decreased from their 1995/97 values, perhaps giving rise to social and political tensions. FAO (2000d) similarly suggests that some South Asian countries may have insufficient income growth to decrease by Year 2030 their numbers of poor persons.

For the near term (1999-2008), annual-average growth rates for *total GDP* (not income) are forecast by FAO (2000d Figure 2.3, adapting World Bank 1999) to be 6.2 % / ann for East Asia (developing countries) and 5.1 % / ann for South Asia, compared respectively to 8.5 and 5.8 % / ann during 1991-98. Recent estimates (ADB 2002) are that by Year 2003 *overall GDP* growth rate may in all South-Asian rice-growing countries reach or exceed 5.0 % / ann. Estimates for growth rates in *per person GDP* (and for the longer term, 1995/97 to 2030, FAO 2000d Table 2.4) are listed in Table 7.

Table 7: Forecasts for *per person* GDP annual growth rate for East Asia and South Asia: 1995/7-2030

Location Date	1995/97 - 2015	2015 - 2030	1995/97 - 2030
East Asia	4.9 %	5.7 %	5.3 %
South Asia	3.6 %	4.0 %	3.8 %

[Source: FAO 2000d.]

3. Country-specific trends and projections

3.1 The major rice-growing nations

3.1.1 Food deficit and depth of hunger

Suggestions for FAO-supported interventions must necessarily relate to *national*, and often sub-national, circumstances and much less to the aggregate regional situations represented by the statistics in Tables 1, 2, 3, 5, 6 and 7. Interventions-relevant statistics (adapted from FAO 2000b, 2001b, UNICEF 2000, and IRRI 1997) are therefore presented in tables 8 to 15 for each of the seventeen Asian countries that annually harvest at least 0.6 Mha of rice. Among those seventeen countries, no fewer than eleven are classified as *Low-Income Food-Deficit Countries.* Those eleven comprise Bangladesh, Cambodia, China, India, Indonesia, DPRKorea, Laos, Nepal, Pakistan, Philippines and Sri Lanka. Each of them participates in the FAO-facilitated Special Programme for Food Security.

Moreover, FAO (2000h) lists most of those eleven countries as belonging to the group (also numbering eleven) falling within the two *most-severe categories* (Categories 4 and 5) of *prevalence-plus-depth of hunger.* These latter eleven are Bangladesh, Cambodia, India, DPRKorea, Laos, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, and Viet Nam; (Indonesia, also, may now be Category 4).

The calculation of depth of hunger *(dietary-energy deficit)* is somewhat arbitrary. Nonetheless, and adapting from Singh (2001a, Table 3), we here suggest that for those persons *already* (arbitrarily) pre-designated as "hungry", their calorie intake as a proportion of a 2 300 kcal/ person.day requirement is about 60 percent in Bangladesh and DPRKorea, and 62 - 64 percent in Cambodia, India, Laos, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand. For China, FAO 1999a Annex 3 permits the conclusion that the poorest 10 percent of the populace has a calorie intake of only 70 percent of requirement.

As previewed earlier, we here record the association, at national level, of *intensity of hunger* with the type of rice-system *water regime*. Quantitative indicators for the relative extents of the four types of water regime have been tabulated by IRRI (1997 Appendix-Table 3). Using that tabulation, it may be determined that of those eleven fore-listed countries with *most-severe prevalence-plus-depth of hunger,* no fewer than ten, with Pakistan the exception, have at least 10 percent (and often much more) of their riceland as *rainfed lowland.* Three of those ten (Bangladesh, Cambodia, and Viet Nam) have at least 10 percent of their riceland in both of the categories *rainfed lowland* and *rainfed floodprone (deep-water).* Two others (DPRKorea and Laos) have 10 percent or more of their riceland in each of the categories *rainfed lowland* and *rainfed upland.* Three countries (India, Nepal, and Thailand) have more than 10 percent of their riceland in *all three rainfed* categories. Eight of the ten countries - Bangladesh, Cambodia, India, DPRKorea, Laos, Nepal, Philippines and Viet Nam - also have substantial rates of poverty.

[This analysis provides additional justification - if any be needed - for the emphasis accorded to irrigation and water-management support within the FAO-assisted Special Programme on Food Security.]

3.1.2 Statistical considerations

In Tables 8 to 15, some statistics necessarily pre-date the 1997-99 economic crises that affected several countries in North-East Asia and South-East Asia; (these Tables' data are correspondingly grouped as North-East Asia, South-East Asia, and South Asia). The entries in the eight Tables quantify and reinforce the existing general awareness of the magnitudes of food-security issues and of agricultural resources, productivity, and trade for the seventeen countries. They can correspondingly help identify individual countries' *comparative advantages* and their consequent opportunities wherewith FAO and other agencies could assist member governments to target interventions in support of their rice-region communities and enterprises. They can help identify also the national requirements to expand markets and to strengthen infrastructures, policies, and technologies.

Procedurally, and in recognition of the great disparity among the seventeen countries in terms of rice-growing area, human population, and other statistics (China: 32 Mha riceland, 1.24 B persons; Laos: 0.7 Mha, 0.005 B persons), several data and their interpretations are presented on a "per person" and a "per hectare" basis, so that inter-comparisons may realistically be effected. It is here recognized that in some countries' censuses (agricultural and demographic) the recorded annual totals for individual-crop production may be systematically inaccurate. Also, the human-population totals may fail to record all resident persons; and the non-recorded persons are most likely to be poor persons.

Thus, some population-derived statistics - such as available food energy (kcal) per person or particular-crop production per person or GNP per person may in absolute terms be over-optimistic in relation to food insecurity and poverty. However, since any shortcomings in the census compilations probably affect the whole sequence of a country's population totals, and not just those for any individual census, then the forecasts, interpretations, and recommendations made here and elsewhere in terms of *trends* (growth rates) and of *relative* (rather than of absolute) values are likely to be valid despite these shortcomings. For properties that under-standably exhibit year-to-year variations - as in crop production and international trade - the Tables present *indicative values* for recent triennia (usually 1997-99). Some social and human-nutritional data derive from surveys of the early 1990s.

[It is possible that in their programmes for decentralized planning and implementation of rice-region food-security / poverty interventions, national agencies may find that the format of Tables 8 - 15 can usefully be adapted to portray pertinent statistics at province or state level. It is also pertinent to indicate that FAO's Medium-Term Plan,
recognizing the short-comings in some agricultural statistics, has a new activity and an ongoing Asia-Pacific Regional project to evaluate and to improve statistical-data quality.]

3.2 Demography, poverty and hunger

3.2.1 Demography and food production

Table 8 features aspects of rice production, and of human nourishment. Rice production *per person* (total population) ranges from as little as 40 - 45 kg / person.ann (Iran and Pakistan) to as much as 360 - 390 kg / person.ann for the rice exporters Myanmar, Thailand, and Viet Nam. Values for the proportion of rice in total kcal / person.day, which range from 5 percent for Pakistan to almost 80 percent for Cambodia and Myanmar, relate to Year 1992: values at Year 2002 are likely to be lower than the listed values; the listed values nonetheless provide reliable indicators of relativities. For five countries only (China, RoKorea, Malaysia, Pakistan and Philippines) do animal, including dairy, products exceed 15 percent of the total calories intake. Percentage *growth rates* (1990-2000) in rice *production* are seemingly highest for Cambodia, Laos, Myanmar, Pakistan and Viet Nam.

Table 8: Rice production and human nourishment: Asian rice-producing countries

Country (by regional group)	Rice production (Mt/an; and kg /person	Rice production growth rate (% / an)	Kcal / Person.day at 1998	Rice in total kcal /pers.day (%)	Kcal by veg'ble and by animal (% / %)
China	198 ; 160	0.7	2 972	35	82 / 18
DPRKorea	2.0 ; 85	?	2 000 ?	38	94 / 6

RoKorea	7.2 ; 160	0 ?	3 069	35	84 / 16
Cambodia	3.6 ; 330	6.2 ?	2 078	80	92 / 8
Indonesia	49 ; 240	1.2	2 850	56	95 / 5
Laos	1.8 ; 330	4.4	2 175	67	94 / 6
Malaysia	2.0 ; 95	0.5	2 901	33	82 / 18
Myanmar	17 ; 360	3.6	2 832	77	96 / 4
Philippines	11 ; 155	1.9	2 288	40	85 / 15
Thailand	23 ; 390	2.8	2 462	56	88 / 12
Viet Nam	29 ; 375	5.5	2 422	70	90 / 10
Bangladesh	29 ; 240	2.6	2 050	74	97 / 3
India	128 ; 130	2.0	2 466	31	93 / 7
Iran	2.5 ; 40	1.4	2 822	?	90 / 10
Nepal	3.6 ; 160	2.4	2 170	35	93 / 7
Pakistan	6.8 ; 45	4.4	2 447	5	84 / 16
Sri Lanka	2.5 ; 135	0.9	2 314	41	94 / 6

[Notes: Sources are FAO (2000b, 2001b), IRRI (1997), and UNICEF (2000, 2001); ? indicates doubtful or not reported. Regional groups: North-East Asia, South-East Asia, and South Asia. Several statistics pre-date the 1997-99 economic crises in North-East Asia and South-East Asia. Rice production (Mt / ann and kg / person.ann) is representative of 1997-99; growth rate (% / ann) is for 1990-2000. Rice (%) in total kcal / person.day relates to Year 1992. Proportions of total dietary kcal energy supply - vegetable sources / animal sources - are at 1998-99.]

Table 9 indicates aspects of human population, poverty and undernourishment, and also rice production (repeated from Table 8). Thus, for all of the listed countries for which rice supplies 60 percent or more of the total kcal / person.day, the annual rice-production growth rate achieved during 1990-2000 (Table 8) is encouragingly higher than the annual population growth rate predicted for 1996-2010 (Table 9). However, for several of those countries for which rice supplies between 30 and 60 percent of the kcal/ person.day, there is urgent need to use the methodology previewed for rice yield in chapter 1.2.3 to determine whether the rice-*production* growth rate during 1994-2000 exceeded the forecast 1996-2010 population-growth rate. For some of them - including the three major producers China, India and Indonesia - it perhaps did not.

3.2.2 Undernourishment and poverty: country-specific features

With the afore-mentioned exceptions of Bangladesh, Cambodia, Laos, Nepal and DPRKorea, and with the proviso that some countries' populations may have been underestimated, *average* values (1998 data) for k-calories/ person.day (Table 8) are for most of the seventeen countries sufficient to satisfy national dietary kcal energy supply. Globally, at Year 2030, the average (including industrialized *and developing* countries) dietary energy supply is forecast to exceed 3 000 kcal/ person.day. Nonetheless, at Year 2001 - because of *inequity in purchase-power* access to the available food, and because of *seasonal shortages* of food, which impact severely on growing children, seven of the seventeen listed Asian countries (Table 9) still have alarmingly high rates (> 40%) of moderate and severe infant (under-fives) undernourishment. For most of these countries, rice provides a considerable proportion of the dietary energy supply. The table 9 statistics for *birth weight* pre-date the East-Asian economic crises. They nonetheless indicate most encouragingly that for seven listed countries (China, Indonesia, Iran, RoKorea, Malaysia, Philippines and Thailand) the proportions of babies having birth-weight >2.5 kg are comparable to those for industrialized countries. Conversely, for Bangladesh, India, Myanmar and Pakistan, and probably for Cambodia and Nepal, and possibly for Sri Lanka, the incidence of *low birth weight* is worryingly high.

Table 9: Rice production; population, poverty, and undernourishment: Asian rice-producing countries

Country (by regional group)	Rice prod'tion (Mt/an; and kg /person)	Under-five under-weight (%)	Low birth weight (%)	Poverty (<1 US$ / day) (%)	Population at 1998 (Million)	Pop'l'n growth rate 1996-2010 (% / an)
China	198 ; 160	16	9	19	1 239	0.7
DPRKorea	2.0 ; 85	60	?	?	23	0.7

RoKorea	7.2 ; 160	?	9	2	46	0.6
Cambodia	3.6 ; 330	52	?	?	11	1.5
Indonesia	49 ; 240	34	8	15	204	1.2
Laos	1.8 ; 330	40	18	?	5	2.2
Malaysia	2.0 ; 95	19	8	4	22	1.6
Myanmar	17 ; 360	39	24	?	47	1.1
Philippines	11 ; 155	28	9	27	75	1.7
Thailand	23 ; 390	19	6	2	61	0.9
Viet Nam	29 ; 375	41	17	?	77	1.2
Bangladesh	29 ; 240	56	50	29	126	1.5
India	128 ; 130	53	33	44	980	1.3
Iran	2.5 ; 40	16	10	?	62	1.7
Nepal	3.6 ; 160	47	?	38	23	2.1
Pakistan	6.8 ; 45	38	25	31	132	2.3
Sri Lanka	2.5 ; 135	34	25	7	19	1.1

[Notes: Sources are FAO (2000b and 2001b), IRRI (1997), and UNICEF (2000 and 2001); ? indicates doubtful or not reported. Regional groups comprise North-East Asia, South-East Asia, and South Asia. Several statistics pre-date the 1997-99 economic crises that affected several countries in North-East Asia and South-East Asia. Rice production (Mt / ann and kg / person.ann) is representative of 1997-99; growth rate (% / ann) is for 1990-2000. Data for proportion of children (aged less than five years) who are moderately or severely under-weight (undernourished), and for birth weight, and for poverty derive from various pre-1999 surveys.]

Similarly, the *incidence of poverty* (Table 9, pre-crisis surveys for some countries) is distressingly high in Bangladesh, China, India, Nepal, Pakistan and the Philippines, and also almost certainly in DPRKorea and Viet Nam. FAO (1998b) categorizes Cambodia, Laos and Myanmar as being among "the poorest of the poor". Though not indicated in Table 9, levels of income inequity/inequality are recorded (FAO 1998b, UNICEF 2000) as being disconcertingly high (among countries for which analyses are possible) in Indonesia, Malaysia, Nepal, Philippines and Thailand, and in China and Viet Nam.

*[It is here suggested that the **relativities** within the internationally-compiled Table 9 indications of poverty are probably valid. It is nonetheless necessary to caution that, because of their country-specific procedures of survey / analysis, **national** assessments of poverty and of undernourishment may differ greatly from the percentage values presented in Table 9.*

*Thus for India, the poverty percentage (44 percent) listed in Table 8 **differs substantially and meaningfully** from the Government value of 26 percent (via Singh 2001a, Table 15). Moreover, changes from time-to-time in national methodology and its threshold values for component variables introduce some variation into the time-series of poverty percentages that may distort reality. Thus seven successive all-India rural surveys (at 1983, 1988, 1993, 1994, 1995, 1996, and 1998, Kumar, personal communication, 2001) for percentage poverty among farm households generated the following sequence: 42, 31, 29, 25, 21, 20, 22; the non-monotonic nature of this sequence may be an artefact - but if it be real, it merits careful investigation.]*

Within the *four most-populous* rice-producing countries (China, India, Indonesia and Pakistan) there resided at 1995/97 three-fourths of the global total of undernourished persons (adults and children). At 2015, of the projected *global decrease* (390 M) in the number of undernourished persons - a decrease consequent upon the forecast for those countries that their dietary energy supply shall increase to 2 700 kcal/ person.day - these four populous countries (and their rice systems) shall in aggregate facilitate four-fifths of that global decrease in undernourishment.

3.3 Agricultural production

3.3.1 Cereals

For the seventeen rice-growing countries, and for eight field-crop-commodity groups and for livestock and for inland-fish, Tables 10 and 11 list the national-average production / person (food + feed, indicative, 1997/99)

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and the average annual growth rate in production (1999-2000). Rice data (listed also in Tables 8 and 9) are again listed for ease of comparison with other commodities. However, in comparing kg/ person productions of cereals with those of tubers, fruits, vegetables, and milk, it will be recalled that for the latter commodities much of the mass is contributed by water. Additionally, this document cautions that for some countries the annual estimates for crop yield and production may be imprecise and/or systematically inaccurate.

Wheat - because of climatic constraints - may be profitably grown only in parts of China and in the South-Asian Indo-Gangetic Plains; annual growth rates for national wheat production are there appreciably higher than for rice. Among the listed countries, wheat production per person is highest in Iran, Pakistan and China (Table 10). Most of the listed countries annually import appreciable quantities of wheat flour and wheat products.

Maize and *oil-crops*, including oil-seed field crops and coconut- and palm-oil tree crops, are in most of the listed countries, and particularly in China and during 1999-2000, each increasing in production more quickly than rice (Table 10), and more quickly than human populations, and are forecast to continue to do so, as populations generally become more affluent. (Table 3 aggregates pertinent forecasts for all developing countries). These rising productions are meeting demands both for human food and, increasingly, for livestock feed.

[Global requirement for wheat-plus-coarse-grains is forecast to increase from 107 Mt/ann in 1996 to 200 Mt/ann in 2015 and 270 Mt/ann in 2030. North America, Western Europe, and Australia - each prospective donors to help decrease poverty in Asia - shall be the main suppliers of any Asian shortfalls in domestic productions of these commodities.]

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Table 10: *Per person* production (food + feed, representative, 1997-99), and growth rate in total production (indicative, 1999-2000), for major food/feed groups: Asian rice-producing countries

Country (by regional group)	Rice (kg/per;%/an)	Wheat (kg/per;%/an)	Maize (kg/per;%/an)	Roots + tubers (kg/per;%/an)	Pulses (kg/per;%/an)	Oil-crops (kg/per;%/an)
China	160 ; 0.7	90 ; 1.3	110 ; 2.5	140 ; 3.2	4 ; 2.3	10 ; 4 ?
DPRKorea	85 ; ?	7 ; 2 ?	60 ; 0 ?	35 ; 0 ?	12 ; 0 ?	3 ; 0 ?
RoKorea	160 ; 0 ?	<1 ; 0 ?	2 ; 0 ?	20 ; 0 ?	1 ; 0 ?	1 ; - 4 ?
Cambodia	330 ; 6.2	-	5 ; 0 ?	10 ; 0 ?	1 ; -2 ?	2 ; 2.2
Indonesia	240 ; 1.2	-	45 ; 4.4	90 ; 0 ?	43 ; 3 ?	45 ; 7 ?
Laos	330 ; 4.4	-	20 ; 4 ?	40 ; - 3 ?	3 ; 2 ?	2 ; 7 ?
Malaysia	95 ; 0.5	-	2 ; 5 ?	25 ; 0 ?	?	510 ; 6 ?
Myanmar	360 ; 3.6	2 ; 0 ?	6 ; 6 ?	7 ; 5 ?	30 ; 14 ?	9 ; 5 ?
Philippines	155 ; 1.9	-	60 ; 0 ?	40 ; 0 ?	1 ; 0 ?	20 ; 0 ?
Thailand	390 ; 2.8	<1 ; 0 ?	75 ; 2.5	290 ; - 2.1	6 ; 0 ?	15 ; 4 ?
Viet Nam	375 ; 5.5	-	20 ; 10?	50 ; -2.8	3 ; 3 ?	4 ; 3 ?
Bangladesh	240 ; 2.6	13 ; 7 ?	<1 ; 0 ?	16 ; 2.3	4 ; 0 ?	1 ; 1 ?
India	130 ; 2.0	70 ; 3.7	11 ; 2.8	30 ; 3.8	15 ; 0.7	9 ; 2 ?
Iran	40 ; 1.4	160 ; 0 ?	15 ; 20?	55 ; 3 ?	9 ; 0 ?	2 ; 3 ?
Nepal	160 ; 2.4	45 ; 4.1	60 ; 1.5	45 ; 4.8	9 ; 3 ?	2 ; 1.8
Pakistan	45 ; 4.4	130 ; 3.2	10 ; 1 ?	13 ; 7 ?	9 ; 1.0	5 ; 2 ?
Sri Lanka	135 ; 0.9	-	2 ; 0 ?	20 ; -5 ?	2 ; - 6 ?	15 ; 0 ?

[Notes: Source is FAO (2000b and 2001b); ? indicates doubtful or not reported; - indicates the crop cannot profitably be grown. Regional groups comprise North-East Asia, South-East Asia, and South Asia. Some statistics pre-date the 1997-99 economic crises that affected several countries in North-East Asia and South-East Asia. Crop production (kg / person.ann) is representative of 1997-99; growth rate is for 1999-2000 - however, for some cereals and countries, production was roughly constant during 1996-98. Oil-crop production is represented by "oil equivalent".]

Within these all-cereals totals, contributions at 1996, 2015 and 2030 from *rice* are recorded / forecast for East Asia as 106, 102 and 98 kg / person.ann (while for East Asia excluding China as 130, 131 and 126 kg / person.ann), and for South Asia as 82, 89 and 84 kg / person.ann. Indeed, FAO forecasts that the *rice / person.ann* shall for many countries stabilize at the Year-2000 values. Correspondingly, much of the all-cereals *food* increases (at 2015 and 2030) shall be provided by *wheat* - of which rice-growing countries, including rice-and-wheat-growing countries, shall make substantial imports - though as IFAD (2001) emphasizes, the poor and very poor are unlikely to be consumers of these wheat imports.

3.3.2 Edible-oil crops

In Asian rice-growing countries *edible-oil-crop products* at 1995/97 (Table 10) contributed *substantially less* than the nutritionally desirable 10 to 12 percent of dietary calories (FAO 2000b). However, between 1995/97 and 2015, such products are predicted to provide *one in three of all additional* developing-country calories. To meet this increasing edible-oil demand, the required growth rate in oil-crop production shall be a modest 2% / ann during 2002-2030, compared to the 4% / ann of the 1980s / 1990s. *Palm-oil*, of which rice-growing Indonesia, Malaysia and Thailand are dominant producers, has been and shall continue to be a major contributor to the lessening of undernourishment; conversely, Asian production of *coconut oil* has in recent years remained roughly constant.

For *soybean*, a current and prospective component of rice-system cropping - though soybean oil is less price-competitive than palm-oil and palm-kernel oil - area and production are in Asia each increasing appreciably. Table 3 forecasts the 1996-2030 growth rate in soybean production - aggregated for all developing countries, including the major producers China and India - as 2.6% / ann. However, for *oil crops* in aggregate - as for meat and livestock - FAO (2001c and 2001d) describes for 1999-2000 a considerable *global over-supply* and an appreciable decrease in prices, such that between 1997/99 and 2000 the FAO oils/fats-price index declined

from 140 to 89; however, during 2001, *palm-oil* prices recovered from their Year-2000 value. Notably, the USA is an increasingly price-competitive supplier of edible-oil products.

3.3.3 Fruits and vegetables

Fruits, *vegetables*, *pulses* and, to a lesser extent, *roots and tubers* are important for providing balanced nutrition within a cereals-dominated human diet. For *pulses* (Table 10), only India and Myanmar are major producers; India's rate of pulse production has during recent years increased only slightly. For roots and tubers - dominantly sweet potato, potato, and cassava, China, Indonesia and Thailand are the main Asian producers (Table 10). For *root crops*, the Asian area (about 7Mha) of *sweet potato* is decreasing. For *potato*, some of which is grown in sequence with lowland or upland rice, the area, though small at 7 Mha, is increasing; yield and production also are increasing. For *cassava*, and in part in response to changes in European Union practices, there was a decrease in area planted (to 3.5 Mha at 1997-2000). Such decrease may provide a valuable opportunity to lessen upland-soil erosion if the cassava shall be replaced by crops that provide more-extensive and more-prolonged ground cover during the intense-rainfall season. (In Viet Nam, cassava is incorporated within erosion-control programmes.)

Table 11: *Per person* production (representative, 1997-99) and growth rate in total production (indicative, 1999-2000) for major foods and food groups: Asian rice-producing countries

Country (by regional group)	Rice (kg/per; % /an)	Fruits (kg/per; % /an)	Vegetables (kg/per; % /an)	Total meat (kg/per; % /an)	Total milk (kg/per; % /an)	Inland fish (kg/per; % /an)
China	160 ; 0.7	40 ; 10?	190 ; 8.7	45 ; 8 ?	8 ; 5.0	2 ; 12 ?
DPRKorea	85 ; ?	50 ; 0 ?	140 ; 0 ?	7 ; -6 ?	4 ; 0 ?	1 ; 0 ?
RoKorea	160 ; 0 ?	50 ; 2.8	230 ; 1.2	35 ; 5 ?	45 ; 2.6	<1 ; -10 ?
Cambodia	330 ; 6.2	30 ; 3 ?	40 ; 0 ?	15 ; 4 ?	2 ; 1.9	7 ; 5 ?
Indonesia	240 ; 1.2	40 ; 3 ?	25 ; 4 ?	10 ; 3 ?	4 ; 2 ?	2 ; 0 ?
Laos	330 ; 4.4	30 ; 3 ?	30 ; 5 ?	15 ; 6 ?	1 ; 2 ?	5 ; 5 ?
Malaysia	95 ; 0.5	50 ; 0 ?	25 ; 4 ?	50 ; 5 ?	2 ; 2.5	<1 ; 10 ?
Myanmar	360 ; 3.6	25 ; 3 ?	60 ; 5 ?.	9 ; 6 ?	13 ; 2.6	3 ; 0.8
Philippines	155 ; 1.9	140 ; 2 ?	70 ; 2 ?	25 ; 6 ?	<1 ; 0 ?	2 ; - 4 ?
Thailand	390 ; 2.8	120 ; 1.6	45 ; 1.0	30 ; 2.5	7 ; 15 ?	3 ; 6 ?
Viet Nam	375 ; 5.5	50 ; 3.1	60 ; 3 ?	20 ; 6.4	1 ; 2.0	1 ; 0 ?
Bangladesh	240 ; 2.6	12 ; 0.2	13 ; 2.8	3 ; 4 ?	17 ; 3.1	4 ; 3.9
India	130 ; 2.0	40 ; 5 ?	60 ; 2.4	5 ; 2.1	75 ; 3.7	<1 ; 5 ?
Iran	40 ; 1.4	170 ; 5 ?	220 ; 5 ?	23 ; 4 ?	85 ; 3.7	2 ; 10 ?
Nepal	160 ; 2.4	20 ; 0 ?	60 ; 3 ?	10 ; 2.7	50 ; 2.7	<1 ; 5 ?
Pakistan	45 ; 4.4	40 ; 4 ?	30 ; 4 ?	17 ; 2 ?	160 ; 5 ?	1 ; 6 ?
Sri Lanka	135 ; 0.9	45 ; 2 ?	35 ; 1 ?	5 ; 6 ?	16 ; 1.3	1 ; 0 ?

[Notes: Source is FAO (2000b and 2001b); ? indicates doubtful or not reported. Regional groups comprise North-East Asia, South-East Asia, and South Asia. Some statistics pre-date the 1997-99 economic crises that affected several countries in North-East Asia and South-East Asia. Crop production (kg/person.ann) is representative of 1997-99; growth rate is for 1999-2000 - however, for some cereals and countries, production was roughly constant during 1996-98.]

For *vegetables*, including cabbage, and for *fruits*, growth rates in production, though somewhat uncertainly determined, are for almost all of the seventeen countries appreciably and encouragingly higher than rates of population increase (Tables 9, 11). Among the listed countries, the substantial (per person) fruits and vegetables producers are Iran, China, DPRKorea, RoKorea, the Philippines and Thailand. *[However, FAO (1999a) cautions that many poor-family producers of fruits and vegetables perforce sell their produce, and do not themselves receive the balanced-diet benefits from their production - except perhaps through consumption of blemished items.]*

3.3.4 Livestock products

For *livestock and products* (Table 11), Asia's major (per person) producers of meat - predominantly pig meat and poultry meat - are China, RoKorea, Malaysia, Philippines and Thailand. Prominent Asian producers of milk (including cow milk and buffalo milk) are RoKorea, India, Iran, Nepal and Pakistan. Production per person of eggs, predominantly hen eggs, increased very substantially during recent years - notably in China, and is forecast to continue to increase. For the periods 2000-2015-2030, FAO (2000d) and Steinfeld *et al* (1997) forecast that the annual growth rates for *livestock products* shall be about twice the growth rates for crops.

Growth shall derive initially from an increase in animal numbers - particularly of poultry and pigs, as compared to ruminants, and subsequently from increased weight per animal - facilitated by food supplements and concentrates (FAO 1999c). Growth shall result also from shorter growth cycles, from increased littering (pigs), and more-efficient feed-conversion (poultry).

However, the rate of increase in animal populations and in demand and production of meat is expected to slacken during 2002-2030: of the major consumers, China is already relatively well-nourished - though FAO 1998b Annex 3 Table 27 forecasts a doubling during 1996-2020 in the per person consumption of red meat, and India is not likely to become a meat-eating country. For mixed smallholder farms, it is highly pertinent (IFAD 2001) that *small* livestock grow and breed more quickly than large livestock. Moreover, smallholder populations of *large* ruminants may be constrained by decrease in average (mixed) farm size (LEAD 1999).

Table 11 includes values also for the per person production from *inland (lake and river) capture fisheries.* Such values probably do not include any fish production from rice fields; they are nonetheless here presented as an indication of prospective market opportunities for rice-fish enterprises, and possibly for rice-system crabs and shrimps. However, less than 1 percent of the Asian riceland area is currently used for rice-fish culture, whether concurrent or sequential (Funge-Smith, personal communication 2002). This notwithstanding that more than 100 fish species are suited to Asia's fresh-water and brackish-water ecozones, and that moderate-intensity rice-fish systems can typically produce 1 t fish / ha.year. Correspondingly, the number of rice holdings that harvest fish is a small fraction of the number that raise livestock. Nonetheless, crabs and shrimps - in addition to finfish - are cultivated in the Chinese *rice systems*; their production is forecast to increase throughout 2002-2030 (Dixon *et al* 2001).

In most rice-growing countries, however, the cultivar-induced shortening of the rice season, the lessening of the submergence-water depth, and the increased use of ricefield agro-chemicals, are severely constraining the living aquatic resource. That resource had heretofore included many specifically-adapted non-introduced species, including catfish, snakehead, gourami, indigenous cyprinids, eel, frog, snail, shrimp, and crab. The protein from the "by-catch" from that resource previously helped diversify cereals-dominated rural diets, or substituted own-farm-produced livestock protein which could thereby be sold for cash income - particularly among the poorest rural dwellers. That lost by-catch protein shall need to be replaced - either from fish or from livestock species.

The Asia-Pacific production of shellfish and finfish in *aquaculture systems* (predominantly in China) is some six times higher than the production from inland capture fisheries. During 1989-99 it grew at the extremely high rate of 13 % / ann, and is forecast (ADB 2001a) to continue that rate of growth. Globally, aquaculture currently produces about one-third of human-consumed fish; that proportion shall rise to one-half by 2030. Some of the aquaculture systems are constructed on converted ricelands. Regrettably, in some coastal ecozones those systems are non-sustainable, and are soon abandoned; but their soils are then unsuited to rehabilitation for rice

[Rice-fish systems, and aquaculture systems, feature in the ongoing activities in the Asia-Pacific Group of the FAO (2000a) Fisheries Department.]

3.4 Human and physical resources

3.4.1 Human resources

Tables 12 and 13 quantify the *human and physical resources* that facilitate rice-system production and rice-community livelihood in the seventeen specified countries. The quality of *human resource* is in Table 12 represented by secondary-school-enrolment percentages for males and for females. These data (UNICEF 2000, quoting UNESCO) pre-date the 1997-99 crises. They nonetheless indicate valuable strengthenings of human resources compared to the "Green Revolution Era" *circa* 1980. These higher educational attainments - notably in literacy and (less-often appreciated) in numeracy - shall facilitate the adop-tion of more-complex farming concepts and techno-logies and technology packages. They shall facilitate also the management, including financial manage-ment, of rural enterprises, and shall strengthen the ability to recognize pertinent opportunities. *Women's education* shall provide a crucial resource wherewith to combat rural poverty and undernourishment.

Table 12 indicates also that in East Asia (excepting Cambodia and Laos) female secondary-school-enrolment is comparable to that for males. In South Asia - and particularly in Bangladesh, Nepal, and Pakistan - female enrolment is substantially less than male enrolment, and more so in rural than in urban areas (IFAD 2001). However, gaps are slowly narrowing; and the female and male "net *primary-school-attendance* percentages" are becoming more-nearly equal. Crucially, women's representation in parliaments and in governments is being increasingly legally strengthened (ADB 2001a, IFAD 2001).

For poor rural households (whether landed or landless), the resource represented by *non-farm employment and income* (not quantified in Table 12) is almost always vital for the household's enterprises, food security, and wellbeing - particularly for farms that lack access to irrigation or to supplemental water. Such employment helps also the construction of social capital and assets.

Table 12: Indicators for *human and land* resources which facilitate rice-system production and livelihood: Asian rice-producing countries

Country (by regional group)	Education : Sec'n'dy school enrolment (% M ; F)	Agricultural land area (Mha)	Agr. pop'l'n. / agric't'l land (person / ha)	Rice area / agric. land (%)	Irrigated area; and gr'wth rate (Mha ; % / an)	Irrigated riceland (estimate) (Mha)
China	74 ; 67	134.7	6.2	23	51.5 ; 1.4	29.5
DPRKorea	? ; ?	? 2.0	3.7	? 30	1.5 ; 0.4	? 0.4
RoKorea	100 ; 100	1.9	2.4	55	1.2 ; -1.8	1.1
Cambodia	30 ; 18	3.8	2.0	51	0.3 ; 1.6	0.3
Indonesia	52 ; 44	31.0	3.0	37	4.8 ; 1.1	? 7
Laos	36 ; 23	0.9	4.8	73	0.2 ; 2.7	0.1
Malaysia	58 ; 66	7.6	0.5	9	0.4 ; 1.0	0.5
Myanmar	29 ; 30	10.1	3.1	54	1.6 ; 6 ?	1.0
Philippines	71 ; 75	10.0	2.9	39	1.6 ; 0.1	2.1
Thailand	38 ; 37	20.4	1.5	48	4.7 ; 1.4	0.7
Viet Nam	44 ; 41	7.3	7.1	98	3.0 ; 0.7	? 4.0
Bangladesh	28 ; 14	8.3	8.3	98	3.8 ; 3.8	? 2.6
India	59 ; 39	169.5	3.2	26	58.1 ; 3.0	? 20.5
Iran	79 ; 69	18.8	1.0	4	7.6 ; 0.9	? 0.5
Nepal	49 ; 25	3.0	7.1	51	1.1 ; 2.3	0.4
Pakistan	33 ; 17	22.0	3.4	11	7.9 ; 0.9	2.4
Sri Lanka	71 ; 78	1.9	4.5	43	0.6 ; 2.1	? 0.6

[Notes: Sources are FAO (2000b and 2001b), IRRI (1997), and UNICEF (2000); ? indicates doubtful or not reported. Regional groups comprise North-East Asia, South-East Asia, and South Asia. Some statistics pre-date the 1997-99 economic crises that affected several countries in North-East Asia and South-East Asia. School-enrolment percentages (male and female) derive from various pre-1997 surveys. Agricultural-land area (Mha) and agricultural population / agricultural-land area (person / ha, derived from FAO 2000b) are at 1998. Irrigated land (all crops) is indicative: Mha for 1997-98, and % / ann for 1988-99. Irrigated-riceland area and irrigated (total) land area may for some countries

derive from different agencies; double-cropped irrigated riceland is generally counted twice, and data for fully and for partially irrigated ricelands are not distinguished; values here are estimated via IRRI (1997).]

3.4.2 Land and water resources

Data for *agricultural-land area* (Table 12) highlight the preponderance of China and India - which together contribute 304 Mha of the 454-Mha seventeen-country total. However, FAO (2000d) cautions that historic data for land area are for several countries unreliable. Notably, of the global total (73 Mha) of land brought newly into cultivation during 1975-95, no less than 70 percent (53 Mha) was devoted to *oil crops.*

Agricultural population per agricultural-land area indicates the prospective intensity of workforce that might be applied to agricultural production and enterprise. It correspondingly indicates that in countries such as Bangladesh, China, Laos, Nepal, Sri Lanka and Viet Nam the rural population per hectare of agricultural land may be so high as to raise concerns for land tenure and land fragmentation and the ability to support mixed crop-livestock systems (LEAD 1999).

The proportion of total agricultural land that is *devoted to rice* varies (among the seventeen countries) from 10 percent or less (Iran, Malaysia, Pakistan) to more than 70 percent (Bangladesh, Laos, Viet Nam) - though for these latter countries the proportions are inflated by the procedure whereby doubly-cropped rice area is counted twice. The countries devoting high proportions of land to rice are also those that have high agricultural population per hectare of agricultural land.

For *irrigation,* FAO (2000d) reports that at 1995/97 about 20 percent of developing-world arable land was irrigated. This irrigation facilitated 40 percent all developing-world crop production - expected to increase to 47 percent by Year 2030 - and 60 percent of developing-world cereals production. Irrigated-land production is more stable year-to-year than rainfed-land production; it correspondingly has higher benefit for food security.

The physical area of irrigated land (all developing countries) - which at 1995/97 was 197 Mha - is forecast to attain 242 Mha at 2030, representing a proportional increase x1.23; the opportunities for additional multiple-cropping raise this factor to x1.34. In *East Asia,* the irrigated area, for rice and non-rice crops, is projected to increase during 1996-2030 from 69 to 85 Mha; for *South Asia,* correspondingly, from 78 to 95 Mha; in each case, an annual compound rate of increase of 0.6 %/ann.

Table 12 indicates that for the seventeen countries, irrigated *riceland* comprises about one-half of the total of irrigated land. FAO (2000c: Facon) reports that in China and in India the allocation of irrigated area among rice, wheat, and other crops is roughly one-third each; while in South-East Asia rice occupies nine-tenths of the irrigated land.

Notably, of the total forecast increase (by Year 2030) in global developing-country arable-land area (double-cropped area counted twice), 38 percent shall be facilitated by expanded irrigation; and that 38 percent land-area increase shall generate 72 percent of the forecast increase in crop production. Within these figures there is accommodation that some irrigated land, notably in South Asia, shall become less productive because of irrigation-induced salinization, ground-water depletion, and water-logging, and that agriculture (including rice smallholdings) shall increasingly encounter responsible demands to divert scarce water to other uses (ADB 2001c, and World Bank in FAO 1997a: Plusquellec). In Asia, agricul-ture currently uses about four-fifths of freshwater withdrawals (Guerra *et al* 1998, FAO 2000c.)

FAO (2000d) suggests that during 2002-2030 the *technical efficiency of irrigation-water distribution / allocation* - the proportion of water released from the irrigation-system head-works that reaches the farmers' fields - may realistically be expected to increase from 38 percent to 42 percent in East Asia, and from 49 percent to 58 percent in South Asia. Somewhat contrarily, Guerra *et al* (1998, citing various sources) report that at 1990-91 such efficiency was in East Asia (Indonesia, Malaysia, Thailand) 35 - 65 percent, but in South Asia (India) only 30 - 40 percent. The concept of *economic efficiency of water* - and of its poverty and social components - is well presented by IFAD (2001 Box 4.10).

For such water as does reach the farmers' fields, the aspect of *water productivity* - which is the amount of produce generated per unit of water applied, is addressed in chapter 4.2.1 of this document. We here note that in relation to prospective irrigation-water savings at field level, IWMI (2000c) documents the substantial

irrigation-water savings achieved in Zhanghe, China - during 1966-98, with progressively increasing rice yields - through the procedure of regular within-season field draining.

Such procedure may by 2030 be supplemented by the option to grow water-efficient "aerobic-rice" cultivars if such cultivars have by then been developed successfully for the upland ecozones. Such cultivars might be particularly appropriate as the second rice in an irrigated or rainfed rice-rice sequence. However, there is need to be mindful of the appreciable benefit to the productivity of current lowland-rice cultivars that derives from the rice-favourable soil-chemical regimes that result from prolonged soil submergence.

Relatedly, Woodhead *et al* (1994) reported that for the Haryana (India) rice-wheat sequences an appropriate combination of rice and wheat cultivars, of land preparation, and of irrigation regime, perhaps including conjunctive use of sweet and brackish waters in appropriately-drained lands, can achieve a 35 - 40 percent field-level irrigation-water saving *(rice and wheat),* with relatively small yield penalty. And for *wheat* in the rice-wheat area of the Pakistan Punjab, CIMMYT (2000a) reported that water-conserving procedures, involving preparatory laser-guided land levelling with subsequent minimum-tillage post-rice seeding of wheat into raised beds, have in farmers' fields demonstrated the capability to save 25 - 40 percent of field-level water requirement (compared to current practice) while attaining a 17 percent increase in wheat yield and in fertilizer-use efficiency.

These findings and forecasts suggest that it is reasonable to expect that there should during 2002 - 2030 be no need for any appreciable increase in water withdrawals for irrigation. However, IWMI (2000a, and 1998 cited by FAO 2000c) estimates that even if Asia-Pacific-Region agriculture does achieve considerable savings of irrigation water by Year 2030, the forecast *increase* by that time in domestic and industrial water requirements shall exceed the irrigation-water saving to such extent that the net requirement for diverted water shall increase by at least one-fifth.

Table 12 indicates that in the seventeen listed rice-producing countries *irrigated-land* area (all crops) and *irrigated-riceland area* (physical area - this author's estimates) are expectedly dominated by China and India - but also, for all irrigated crop-land by Pakistan. Irrigated-riceland area is substantial also in Indonesia and Viet Nam. Annual *rates of irrigated-area increase* (1988-99) were of order 1- 2 %/ ann for a majority of the seventeen countries, but appreciably exceeded 2% / ann in Bangladesh, India, Laos, Myanmar and Nepal; however, these increases *may not* refer to riceland. For *rice and particularly wheat,* FAO (2000d) suggests that future increases in production shall derive more from cultivar improvement than from irrigation expansion.

3.4.3 Mechanization

Mechanization, as represented in Table 13 by the numbers of two-wheeled and four-wheeled tractors - totals aggregated - per 000 ha of agricul-tural land, is furthest developed in the extreme east (the two Koreas) and in the extreme west (Iran and Pakistan) and in Thailand and Viet Nam. Mechanized harvesting is increasingly practised in China, Malaysia, Thailand and the Indo-Gangetic Plains - often on lands that have been consolidated to benefit from contract-servicing of land-levelling, tillage, seeding, and harvesting. For many smallholder rice-system farmers in India, Kumar (personal communication, 2001) concludes that the lack of tractive power, whether gasoline- or animal-derived, delays field operations and lessens productivity.

The cost in Nepal (Rice-Wheat Consortium 2000b) of a Chinese manufactured two-wheel tractor with basic cultivation attachments is US$1 300, compared to an average Nepal income of US$200 / person.ann. In Pakistan (Rice-Wheat Consortium 2000c), the cost of a locally-manufactured wheat-seed drill, which requires four-wheel-tractor power, is US$600. Other aspects of mechanization for post-rice tillage operations were introduced earlier (*via* Rice-Wheat Consortium 2000a).

[Mechanized operations necessarily have implication for the creation and continuance of remunerative and drudgery-free rural employment.]

3.4.4 Nutrient management

Appropriate *integrated nutrient management* in rice-based sequences and systems shall expect to provide or replenish the nutrients removed by the crops, and to increase the soil biomass and thereby improve "soil health", and to facilitate adoption of high-yielding crop cultivars (FAO 2000a). Table 13 therefore lists in two

adjacent columns the annual rate of *mineral fertilizer applications:* N, P, and K nutrients in aggregate, for *all crops* - food and industrial - and representative for 1996-99 (FAO 2000b and 2001b), together with this author's estimate (adapting FAO 2000d, WAICENT) for the application of *nitrogen to rice,* as kg N / ha.ann, and regardless of whether to one, two, or three rice crops per year. These totals relate to manufactured / processed fertilizers only; nutrients from composts and manures would increase these numbers.

The N+P+K-aggregate (mineral) application rate exceeds 200 kg nutrients / ha *per annum* (not per crop) in China, RoKorea and Viet Nam; such rates are sufficiently high that there is risk of adverse environmental impacts. Moreover, previous national-scale analyses (Woodhead, Huke, and Huke 1994 Table 5) documented for rice in Bangladesh, India, Myanmar and Pakistan the strongly *diminishing response to fertilizer* (as kg rice grain / kg fertilizer nutrients) as *national-average* applications increased from 5 to 80 kg nutrients / ha.ann through 1965-75-80-87. However, for *individual fields,* long-term experiments indicated that the *incremental* yield response to increase of fertilizer declined only slightly - if at all - during fifteen years.

Current fertilizer-application rate (Table 13, *all nutrients*) is 40 kg nutrients / ha.ann or less in Cambodia, Laos, Myanmar, and Nepal. For all-India, (Singh, Kumar, and Woodhead 2002 refer) determined that at 1991/92 and for all crops in aggregate, *irrigated land* received about 110 kg nutrients / ha.ann irrespective of farm size (whether <1.0 ha, intermediate, or >4.0 ha), whereas *non-irrigated* land received about 40 kg nutrients / ha.ann on the smallest farms, but only 25 kg nutrients / ha.ann on the largest ones. In all countries, fertilizer applications in the floodprone / swampland, upland, and less-favourable rainfed lowlands are, expectedly, less than these national averages, but may be increasing in some ecozones - as in eastern India (IRRI-IFAD 2000).

Annual *nitrogen-fertilizer* applications per hectare of *rice* - with some imprecision because of uncertainty of rice area in multiple-rice-cropping regions - are for most of the listed countries comparable to the totals of N+P+K nutrients/ha.ann. This N-rate exceeds 160 kg N / ha.annum (not per crop-season) in China, Indonesia, Iran, RoKorea, Malaysia and Viet Nam. It is 30 kg N / ha.ann or less in Cambodia, Laos, Myanmar and Nepal: this low rate of N-fertilization is to some extent reflected (Table 13) in these countries' low *rice yields* (indicative for 1997-2000, and aggregated for rainfed and irrigated rice).

Table 13: Indicators for *on-farm resources* which facilitate rice-system production and livelihood: Asian rice-producing countries

Country (by regional group)	Tractor / agric. land (no. / 000 ha)	Fertilizer / agr. land 1996 -1999 (kg/ha.a)	N-fertilizer / rice-land 1996 -1998 (N / ha.ann)	Rice (rainfed or irrigated) yield (t / ha)	Chicken no. growth rate 1989 -2000 (% / ann)
China	5	265	255	6.3	6.0
DPRKorea	? 35	? 80	?	? 3.8	? 0
RoKorea	83	475	355	6.8	3.2
Cambodia	0.3	3	6	1.8	4.4
Indonesia	2	85	180	4.3	? 3
Laos	1	6	6	2.9	5.1
Malaysia	6	175	165	2.9	? 6
Myanmar	1	16	30	3.2	5.8
Philippines	1	75	90	3.0	7.3
Thailand	11	85	85	2.3	5.0
Viet Nam	17	250	180	4.1	8.5
Bangladesh	1	145	95	3.1	5.3
India	9	100	135	2.9	3.0
Iran	12	55	170	4.2	4.5
Nepal	2	30	20	2.5	3.5
Pakistan	15	120	120	2.9	? 9
Sri Lanka	4	120	130	3.2	1.4

[Notes: Sources are FAO (2000b and 2001b); ? indicates doubtful or not reported. Regional groups: North-East Asia, South-East Asia, and South Asia. Some statistics pre-date the 1997-99 economic crises in North-East Asia and South-East Asia. Tractor numbers (expressed on a per 000 ha basis) include 2-wheeled and 4-wheeled models, and relate to 1996-98. Fertilizer per ha of agricultural land relates to all crops (food and industrial) and includes N, P2O5, and K2O, and is indicative for 1996-99; fertilizer per ha of rice (whether 1, 2, or 3 crops / year) is adapted from FAO 2000d. Rice yield (aggregate for irrigated and rainfed crops) is indicative for 1997-2000. Chicken-numbers growth rate (1989-2000) is here presented as an indicator of very high growth rates in the livestock sector.]

For *rice-rice* systems in southern and north-eastern India, Siddiq (2000) reports the incidence of P, K, and zinc deficiency, and of iron toxicity in some K-deficient areas. For *rice-wheat* cropping, Siddiq describes the progression through the Lower, the Middle, the Upper, and the Trans-Gangetic Plains in the applications of N and P - and also of K, Zn, and farm-yard manure. In aggregate, and for both rice and wheat, applications of N : P_2O_5 : K_2O are in the approximate proportions 6 : 1 : 1 - suggesting that applications of P and especially K are sub-optimal. This suggestion is supported by details - in Siddiq's Table 34 - of the farmer-field benefits, in production and in nitrogen-use-efficiency, of site-specific nutrient management.

Appropriate applications of K and especially P encourage the production of crop roots, and hence of soil biomass, and of ground cover - the latter particularly important for non-rice crops on non-submerged soil. Moreover, farmer-field research results (IRRI 2001a) indicate that for *rice* in rice-rice, rice-wheat, and rice-maize sequences, application of K within appropriate procedures of site-specific nutrient management can increase economic returns by 30 - 50 US$ / ha.crop, and that management of N using those procedures can raise yield by about 10 percent, and - crucially - can increase N-recovery and hence N-use efficiency by 40 percent.

For Year 2020, IFPRI (1996) projects that actual *applications of mineral nutrients* (all developing countries in aggregate) shall be 122 Mt / ann, compared to a total of 185 Mt / ann that shall be required to ensure food security, and of 250 Mt / ann for sustainable resource use. More recently, FAO's (2000b 2000d) listings and forecasts suggest for *global* applications (all nutrients) to *rice* (predominantly Asia) at 1995/97, at 2015, and at 2030 as 22.2, 26.3, 27.6 Mt / ann, to *wheat* (globally) as 24.6, 27.6, 30.1 Mt / ann, and to *maize* (globally) as 22.3, 27.0, 30.3 Mt / ann. The totals for *rice* comprise N, P_2O_5 and K_2O applications as 15.5, 4.6, 2.1 Mt / ann at 1995/97, as 18.3, 5.5, 2.5 Mt / ann at 2015, and as 19.4, 5.6, 2.6 Mt / ann at 2030.

The *average compound rate of increase* of N+P+K fertilizer applications, to *all* crops, during 2002-2030 is forecast FAO (2000d) for East Asia as 0.9%/ann (or 0.6%/ann on a per hectare basis) and for South Asia as 1.3%/ann (or 0.8%/ann on a per hectare basis). IFPRI (1996) estimated that of the total of fertilizers applied in *Asia* (excluding Japan) at 1995 about 70 percent was applied to food crops, as distinct from feed crops and industrial crops. For *India*, Kumar (personal communication, 2001) calculates that at 1991/92 the proportions of (total) N+P+K mineral nutrients applied to rice, to wheat, and to maize were respectively about 35 percent, 20 percent, and 3 percent; the proportionate applications of farm-yard manure were somewhat similar. *Globally*, and for *nitrogen* fertilizers: rice, wheat, and maize respectively received at 1995/97 about 19 percent, 20 percent, and 17 percent of the global total of N, and are each projected (FAO 2000d) to receive about 18 percent of the (increased) global total at 2030. Myanmar, and Pakistan, and probably for Cambodia and Nepal, and possibly for Sri Lanka, the incidence of *low birth weight* is worryingly high.

Because land in rice-producing zones is already used very intensively, and the challenges to achieve food security shall continue to be substantial, it is probable that in rice-based cropping land scarcity shall constrain local opportunities to produce *plant- or large-animal-derived ("organic")* fertilizers. Thus even in India, with its substantial livestock-population totals and densities, the application of farmyard manure on marginal-size holdings (< 1.0 ha) at 1991/92 (Singh, Kumar, and Woodhead 2002) was only 3.8 t / ha.ann on irrigated land and 1.6 t / ha.ann on non-irrigated land, and that on farms larger than 4.0 ha these application rates decreased to 2.0 t / ha.ann and 0.6 t / ha.ann.

However, *poultry manure, composted cattle manure, and piggery slurry and pig manure* are known to be effective sources of nutrients - particularly of nitrogen, phosphorus, potassium, and calcium (Dobermann and Fairhurst 2000 Table 4). These materials shall expect to become more plentiful as livestock populations increase in mixed-farming systems and in industrial livestock-production systems in many rice-growing countries.

Overall, efficient nutrient management in rice systems shall require well-designed and well-implemented policies and programmes for fertilizer supply / distribution / regulation, for prices, incentives, training, credit, and infrastructures, and for environmental monitoring.

[On all these aspects, FAO (2000a) through its Land and Water Development Division has the mandate, expertise, and ongoing activities, including activities within the Special Programme for Food Security, to assist member countries.]

3.4.5 Livestock resources

The importance of the *livestock resource* is featured in Table 13 by the growth rates (1989-2000) in the *numbers of chickens*, whether for meat or for eggs. Only for DPRKorea and Sri Lanka, and possibly India and Indonesia, did these growth rates fail to exceed 3.0 %/ann. For several countries they were substantially higher: approaching or exceeding 6.0 %/ann in China, Malaysia, Myanmar, Pakistan, Philippines and Viet Nam. For all developing-country Asia, annual growth rate for chicken population was 5.0%/ann, and for duck population 5.5%/ann. However, Dixon *et al* (2001) caution that most of these population growths derived from large-scale enterprises and not from mixed-system smallholdings. Moreover, poultry population growth rates are forecast to be appreciably lower during 2002-2030. For cattle, buffalo, pig, sheep, and goat, the Asian-developing-country populations increased respectively by 1.4, 1.0, 1.9, 1.4, and 3.1%/ann during 1989-2000 (FAO 2000b, 2001b).

For India, IFPRI (1999b) suggests that the high growth rates for poultry and ruminant populations bring corresponding requirements and opportunities for the small-scale and large-scale production of feedstocks, and corresponding concerns for disposal of excreta. However, in all rice-growing countries, if the livestock excreta are produced in proximity to ricelands, then such excreta - whether processed on-farm, or by specialist enterprise, or not at all - may be used as a component in the nutritional management of rice-system crops. Indeed, FAO (1999c) reports that on Bangladesh smallholdings the value of the manure constituted two-fifths of the value of large-ruminant production. Correspondingly, by-products and waste and pest products from rice-system crops may be converted, either on-farm or in village-scale enterprises, into feed supplements for rice-system livestock.

[Such crop-livestock synergy features as one of seven thrusts to foster FAO's Medium-Term Plan (2000a) Production-Systems Priority-Area Inter-disciplinary Action.]

3.5 Economics and trade

3.5.1 Rural and national economies

Economic and trade indicators for the seventeen countries are presented in Tables 14 and 15. Values for Gross National Product *(GNP) per person*, at 1998, and hence mid-crises, exhibit strong variation (Table 14): from below US$ 400/person.ann (barely US$ 1.00/person.day) in Bangladesh, Cambodia, Laos, Nepal, and Viet Nam to almost US$ 4000/person.ann in Malaysia and to more than US$ 8000/person.ann in RoKorea.

Table 14: Economic and agro-economic indicators: Asian rice-producing countries

Country (by regional group)	GNP and growth rate ($ / pers; % / an)	Agric. pop'l'n / total population (%)	Agric. pop'l'n change : 1989 to 1999 (%)	Agric. GDP / total GDP (1998/99) (%)	Agricult. empl / total empl'ment (1996) (%)
China	750 ; 6.5	68	+ 4	17	47
DPRKorea	? ; ?	31	- 6	?	38
RoKorea	8600 ; 4.9	9	- 41	5	10
Cambodia	260 ; 0 ?	70	+ 24	48	96
Indonesia	640 ; 4.0	45	+ 2	18	42
Laos	320 ; 3.8	77	+ 29	53	78
Malaysia	3670 ; 4.8	18	- 15	11	16
Myanmar	? ; ?	71	+ 8	52	51

Philippines	1050 ; 1.5	40	+ 8	18	36
Thailand	2060 ; 4.4	50	- 4	11	49
Viet Nam	350 ; 6.5	68	+ 14	25	69
Bangladesh	350 ; 3.2	57	+ 1	28	62
India	440 ; 4.3	55	+ 11	27	? 62
Iran	1650 ; 1.8	28	+ 1	21	39
Nepal	210 ; 2.4	93	+ 27	42	94
Pakistan	470 ; 1.5	51	+ 19	26	42
Sri Lanka	810 ; 3.9	47	+ 4	20	36

[Notes: Sources are FAO (2000b, 2001b); ? indicates doubtful or not reported. Regional groups are North-East Asia, South-East Asia, and South Asia. Some statistics pre-date the 1997-99 economic crises. GNP per person is at 1998, and GNP annual growth rate for 1990-98. Percentage change in agricultural-population total is for 1989-99: increases indicate countries where pressures for land fragmentation may become severe. Agricultural population / total population is at 1999; agricultural GDP / total GDP at 1998-99.]

GNP growth rate (1990-98, pre-crises) also ranges widely: from 2%/ann or less in Iran, DPR Korea, Pakistan and Philippines, to 4%/ann (or more) in India, Indonesia, RoKorea, Malaysia and Thailand, and to 6.5%/ann in China and Viet Nam. Worryingly, for many listed countries - notably South-Asian countries - growth rate achieved during 1990-98 was below the 5%/ann value that shall in future be needed if poverty is to be eradicated.

It is thus reassuring that at April 2002 the Asian Development Bank forecasts for Years 2002 and 2003 average annual *GDP* growth rates for India of 6.4 percent and 5.1 percent for Bangladesh; but for Sri Lanka and Pakistan only 4.5 and 4.0 percent respectively. Corresponding South-East-Asia fore-casts include 5.0%/ann for Malaysia and 4.3%/ann for the Philippines, but only 3.3%/ann for Indonesia and 2.8%/ann for Thailand (Table 15 refers)

For the rice-system farm families, and for the associated landless labourers, it is noteworthy that the real prices of both rice and wheat have declined during recent decades. The *profitability* of rice-sequence cropping probably declined correspondingly in some countries and ecozones - notwithstanding decreases in production costs and increases in yields. Such declines are greater where support prices are so low as to constitute a disincentive to rice-systems farming and a consequent incentive to the adoption of higher-profit, often horticultural, systems - as in peri-urban China following agrarian liberalization. Pro-hungry, pro-poor interventions must ensure that rural small- holders and landless families share in the benefits of these higher-profit systems while retaining the food-security insurance of their staple-food supplies.

Indeed, profitability and production have usually increased where there have been supportive government interventions - as through appropriate pricings and by expansion of irrigation and mechanization and market and credit facilities and of seed- and agrochemical-supply systems and by moderation of tenancy law (Woodhead, Huke, and Huke 1994; Singh and Paroda 1994; Singh 1997). However, such interventions have generally brought greater benefit in irrigated than in rainfed ecozones - and it is the latter ecozones that may be home (interpreting Table 2) to the larger proportions of poor and hungry.

Values for the ratio (at 1999) of *agricultural population to total population* are in Table 14 presented as a proxy for the percentage of population that resides rurally. This proportion is below 20 percent for the countries with higher GNP per person (Malaysia and RoKorea), and approaches or exceeds 70 percent in six of the listed countries: Cambodia, China, Laos, Myanmar, Nepal and Viet Nam.

The *percentage change in agricultural population* (1989 to 1999) is also presented in Table 14. For six countries this change exceeds +10 percent. Comparison with Table 12 indicates that three of them (Laos, Nepal, and Viet Nam) already (at 1999) had high ratios for agricultural population to agricultural-land area. It is probable that in these countries, and in India and Pakistan also, many additional persons shall seek to become owners and/or tenants of part of the finite quantity of farmland.

Three data columns in Table 14 indicate the status of the *agricultural (rural) economy* in relation to the total (national) economy. The ratio of agricultural GDP to total GDP at 1998-99, immediately following the East-

Asian economic crises, is notably high (≥ 40 %) in four predominantly rice-producing countries (Cambodia, Laos, Myanmar, and Nepal) and is substantial (≈ 25 %) in India, Bangladesh, and Pakistan.

Crucially - in relation to interventions to relieve rural poverty and undernourishment and to strengthen rural enterprise and employment - the ratio of *agricultural employment : total employment* is for all countries seen to exceed, and most-often very substantially, the ratio of agricultural GDP : total GDP - implying a need for redirection of resources, investments, and policies if rural impoverishment and under-employment are to be lessened. It is thus pertinent to reiterate that the *cost of a rural workplace* is substantially less than the cost of an urban workplace.

IFPRI (1999b) expresses strongly - in relation to India's cereals farmers - this need for a *policy redirection,* and for a review of current subsidies. The more-general need for a redirection of resources and policies is emphasized, and the attendant difficulties highlighted, by the relativities (Table 15, first column) of the *growth rates* (1990-98) in agricultural GDP and in total GDP: the latter growth rate is in all countries much higher than the former.

[To assist rice-growing member countries to make such redirections, the FAO (2000a) Medium-Term Plan indicates that the Divisions of Commodities and Trade and of Policy Assistance (headquarters and regional) have the required expertise and ongoing programmes.]

Table 15: Economic and trade indicators: Asian rice-producing countries

Country (by regional group)	Historic growth rate of GDP (agric. ; total) (% / an ; 1990-98)	Forecast growth rate of total GDP (2002 ; 2003) (% / an)	Agricultural import; export 1996 - 1998 ($ / ann.person)	Agric. trade / total trade 1991-3 ; 1994-6 (% ; %)	Share of global agricul. trade: ratio of 1994-6 / 1991-3
China	4.3 ; 11.0	7.0 ; 7.4	7 ; 10	6.7 ; 6.5	x 1.44
DPRKorea	? ; ?	? ; ?	17 ; 4 ?	13.6 ; 15.4	x 0.81
RoKorea	2.4 ; 5.9	4.8 ; 6.0	195 ; 38	5.1 ; 4.5	?
Cambodia	2.1 ; 4.9	4.5 ; 6.1	10 ; 4	9.7 ; 13.2	?
Indonesia	2.6 ; 5.3	3.0 ; 3.6	22 ; 28	? ; ?	x 1.73
Laos	3 ? ; 6.5	5.8 ; 6.1	7 ; 12	? ; ?	x 1.64
Malaysia	1.3 ; 6.8	4.2 ; 5.8	19 ; 360	9.1 ; 9.2	?
Myanmar	4.9 ; 6.3	? ; ?	5 ; 6	? ; ?	?
Philippines	1.5 ; 3.2	4.0 ; 4.5	38 ; 25	10.2 ; 8.6	x 1.55
Thailand	2.7 ; 5.2	2.5 ; 3.0	45 ; 140	10.7 ; 5.3	x 0.76
Viet Nam	4.9 ; 8.2	6.2 ; 6.8	12 ; 27	? ; ?	x 2.29
Bangladesh	2.2 ; 4.8	4.5 ; 5.7	11 ; 1	15.5 ; 13.6	x 1.43
India	3.8 ; 6.1	6.0 ; 6.8	4 ; 6	9.6 ; 10.7	x 1.72
Iran	3.8 ; 3.5	? ; ?	53 ; 15	? ; ?	?
Nepal	2.3 ; 4.9	3.5 ; 5.0	8 ; 3	21.7 ; 15.1	?
Pakistan	4.4 ; 4.1	3.0 ; 5.0	14 ; 7	? ; ?	?
Sri Lanka	1.5 ; 5.3	3.5 ; 5.5	43 ; 55	18.5 ; 14.1	x 1.09

[Notes: Sources are FAO (2000b, 2000i, 2001b) and ADB (2002); ? indicates doubtful or not reported. Regional groups are North-East, South-East, and South Asia. Some statistics pre-date the 1997-99 economic crises. Historic growth rates for agricultural and total GDP at 1990-98. Forecasts growth rates for total GDP are for 2002 and 2003. Imports and exports as US$ / person.ann, indicative for 1996-98. International agricultural trade / total international trade (per country, as %) is for 1991-93 and 1994-96 (pre- and post WTO inception); country-specific shares of global international agricultural trade for 1994-96 and for 1991-93 are here expressed as a ratio.]

In the first data column of Table 15, the second number within each pairing quantifies the 1990-98 *historic* growth rate in Total Gross Domestic Product (GDP). The second data column presents very recent informal *forecasts* (ADB 2002) for the GDP growth rate at Years 2002 and 2003 for some of the listed rice-growing

countries. For 2003, for some countries these estimates approach or exceed 5.0% / annum; such growth rate is sufficiently high as to permit cautious optimism that there can be additional *national resources* wherewith to combat rural hunger and poverty. Thus, among the several rice-growing countries that have high incidence of hunger and/or poverty (Table 9), nine are forecast to have at 2003 a GDP that shall be 5.0 percent higher than in 2002 (Table 15). Those nine are: Bangladesh, Cambodia, China, India, Nepal, Pakistan, Philippines, Sri Lanka and Viet Nam.

3.5.2 Rural taxation

Accusations of *anti-rural bias* in regimes of taxation and fiscal policy are regularly made (World Bank 2001a, IFAD 2001). FAO (1998b) queries whether in some instances this bias is actually *anti-smallholder* rather than anti-rural (anti-agriculture). Conversely, FAO (1998b Annex 3) marshals incisive evidence of anti-agriculture / pro-industry bias in China: there is there substantive quanti-tative evidence of a strong government-expenditure bias against agriculture throughout 1965 to 1996 - and continuing (despite policy changes) at 1998.

Furthermore, the Chinese rural sector has since 1985 been subject not only to agricultural tax and agricultural fee but also to tax on Township and Village Enterprises. The rural sector thereby makes a very substantial contribution - which at 1996 was still increasing - to the urban sector and its industry. Additionally, input- and output-price policies - including high taxation on rice, and fertilizer-price control - imposed a further "40 percent disprotection against agriculture" at 1993-94 (World Bank *via* FAO 1998b). Thus, despite good intentions of the Chinese government, "there is disprotection to farmers resulting from procurement / quota / pricing policies". Similar situations may prevail in other rice-producing countries.

Thus FAO (2000i) opines that "in several countries, taxes on agriculture are a substitute for more-imaginative taxes - such as income tax". And suggests (FAO 1998b Annex 1) that even within the agricultural sector, "subsidies - on fertilizer, water, tubewells, electricity, credit - are crowding out necessary investments". Correspondingly, for East Asia, the World Bank (2001a) Regional Strategy Objectives give specific priority to the removal of anti-rural biases.

There are, however, measures with which countries have sought to counter these biases: FAO (1998b Annex 1) reports that macro-economic policies in some South-Asian countries have been successfully directed to removing some pro-industry tariffs, quotas, and licences that had dis-advantaged their rural / agricultural sectors. National policies of low inflation, of realistic currency-exchange rates, and of low human-population growth, similarly have operated (ADB 2000a) to the benefit of rural (and smallholder) interests. Thus, post-crises depreciations of currencies in some North-East-Asian and South-East-Asian countries may have lessened much of that part of the pre-crises taxation that resulted from over-valued exchange rates (ADB 2001a).

[It is thus appropriate to indicate that FAO (2000a) has the technical and legal experience, expertise, mandate, and programmes to assist rice-growing member countries to assess, and if appropriate to strengthen, amend, and/or repeal, their several policies that promote or hinder food security, rural poverty / human nutrition, and agricultural production / processing / pricing and enterprise.]

3.5.3 Agricultural imports and exports

Table 15 provides, in three contiguous data columns, an insight concerning the rice-growing countries' *international agricultural trade* and the implications for that trade of the *World Trade Organization's* procedures and operations. *Agricultural imports and exports* - expressed in US $ / person.ann, and representative for 1996-98, and for food crops and industrial crops in aggregate - indicate for each of the seventeen listed countries the extent to which the country is a net importer or exporter of agricultural products.

Major net agricultural-product *importers* are Bangladesh, Cambodia, Iran, DPRKorea, RoKorea, Nepal, and Pakistan. Major net *exporters* are Malaysia (industrial crops) and Thailand and Viet Nam (food crops). Agricultural imports and exports are more-nearly in balance for China, India, Indonesia, Laos, Myanmar, Philippines and Sri Lanka.

For the net agricultural-produce importers, *interventions* to strengthen within-country comparative advantage to produce, and thence to substitute, high-cost imported food items could be worthwhile. It is thus noteworthy

(Singh 2001b Table 15, adapting FAO 2000d) that at 2015 and at 2030 *East Asia* is forecast to make net imports of 60 and of 79 Mt/ann of (all) cereals, and *South Asia* similarly 16 and 26 Mt/ann.

For *rice*, Asian rice-growing countries' imports and exports are of similar magnitude. Major (consistent 1995-99) rice exporters are India, Pakistan, Thailand, and Viet Nam. Rice importations into rice-growing countries are episodic - responding to individual years' climatic and other circumstances; Indonesia, Iran, Malaysia, and the Philippines each imported substantially during 1995-2001.

For *wheat* and wheat products, all seventeen (Table 15) countries, including wheat-growing countries, are consistent and substantial net importers - though imports were less during the years of economic crisis.

For *all cereals* in aggregate, only India, Thailand, and Viet Nam are net exporters. During 2002-2015, rice-growing countries' requirements for imports of *wheat*, of *coarse grains*, and of *livestock products* are all forecast to increase appreciably. There shall of course be need that the importing countries shall have the resources wherewith to purchase the forecast imports. The major suppliers of the imports are expected to be the Americas (Argentina, Canada, USA), Australia, and various countries of Western Europe.

3.5.4 Global trade implications

The World Trade Organization (WTO) became effectively operational at 1994/95. Two Table-15 columns of data (derived from FAO 2000i, quoting Asian Development Bank) permit preliminary country-specific comparisons of patterns of international agricultural trade before (1991-93 triennium) and after (1994-96 triennium) WTO inception. *[IFAD (2001 Table 5.1) presents similar sample data from continents additional to Asia.]*

A first comparison (from the Table-15 data) assesses for each specified country the percentage *ratio of agricultural trade to total trade* at 1991-93 and at 1994-96. So far as these preliminary data permit any interpretations, it is suggested that for those countries for which any change between 1991-93 and 1994-96 was discernible, and excepting Cambodia and DPRKorea, such change indicates a decrease in agriculture's proportion of the country's international trade. Such decrease implies that agricultural trade increased less rapidly than did non-agricultural trade.

Within global agriculture, however, a more definite pattern emerges: the ratio for 1994-96 compared to 1991-93 shows that for most Table 15-countries (and excepting only DPRKorea, Sri Lanka and Thailand) the share of international agricultural trade - imports plus exports - increased appreciably after WTO inception. For Asia as a whole, agricultural trade increased x 1.37 between 1991-93 and 1994-96, compared to a global agricultural-trade increase of only x 1.25. However, for most Asian countries during 1991-96, agricultural imports increased proportionately more than agricultural exports (FAO 2000i).

Correspondingly, an Association of World Council of Churches survey (1999) concluded that national structural-adjustment programmes, which possibly included trade liberalization components, worsened the food security of poor rural families. Similarly, IFAD (2001, citing various sources) reports that in China, India, and Philippines, increased food prices following liberalization impacted adversely the rural poor. Dixon *et al* (2001) suggest that in developing countries the recent trade liberalization has favoured the urban consumers at the expense of the rural producers, and that such impressions are sustaining a *"A profound unease among developing-country governments concerning the wisdom of trade liberalization"*.

Contrarily, the World Bank (2001b - drafted *after* 11 September 2001) reports that 24 developing countries, with aggregate population of 3 billion persons, that during 1970-90 increased their integration into the world economy have achieved higher growth in incomes, longer life expectancy, and better schooling. Conversely, other countries, of aggregate population 2 billion persons, that did not increase their integration into the global economy have experienced contracting economies, meagre improvements in education, and increased poverty.

The geographic patterns of the rice-growing countries' international trade - and of trade within the regional groupings of ASEAN (Association of South-East Asian Nations), SAARC (South Asian Association for Regional Cooperation), and North-East Asia - exhibit several features that may give insight in relation to prospective interventions.

Thus, adapting FAO 2000i, representative *proportional* statistics for 1994-1996 for *agricultural* food commodities, products, and feeds indicate that of ASEAN's *exports* about 30 percent went to Asian countries,

and less than one-third of that 30 percent to other ASEAN countries, and 70 percent went outside Asia. Of SAARC's *exports*, about 50 percent went to Asian countries, and about one-half of that 50 percent to other SAARC countries, and 50 percent went outside Asia. For North-East Asia, including Japan, about 20 percent of *exports* went to Asian countries, and about two-thirds of that 20 percent to other North-East-Asian countries, and 80 percent went outside Asia.

For *agricultural imports:* for ASEAN, about 30 percent came from Asian countries, with about one-half of that 30 percent from other ASEAN countries, plus rather less than 20 percent from Pacific countries, and 50 percent from outside Asia - notably from developed countries. Of SAARC's *imports*, somewhat less than 20 percent came from Asian countries, and less than one-half of that 20 percent from SAARC countries, plus 10 percent from Pacific countries, and rather more than 70 percent from outside Asia - predominantly from developed countries. For North-East Asia, about 20 percent of *imports* came from Asian countries, and about one-half of that 20 percent from North-East-Asian countries, plus 10 percent from Pacific countries, and 70 percent from outside Asia - notably from developed countries. The dominance of agricultural trade *beyond* Asia and with developed countries is apparent.

Statistics for *absolute* trade, in monetary value, are even more revealing: UK/DFID (2000) and FAO (2000b, 2001b) indicate that during 1997-99 the agricultural exports from the whole of South Asia, with population 1.3 billion persons, were marginally less in value those from Thailand, of population only 60 millions. Thailand's export success reflects in part a commitment to high-quality added-value products.

One interpretation of this foregoing contrast is that in Asia there are substantive constraints to the export of agricultural commodities and products - but that such constraints can be overcome. The several ADB-initiated sub-regional *growth triangles* - as in the contiguous areas of Indonesia, Malaysia, and Thailand - may here have a dynamic role complementary to that of the much-larger regional groupings. There might similarly be commonalities of interest between Bangladesh and India's West Bengal, or between Nepal's Terai and India's Bihar and Eastern Uttar Pradesh. The extent to which global and regional agricultural trade can - and cannot - help lessen hunger and poverty in rice-growing ecozones within the medium term and within the near term is here addressed in the following paragraphs.

3.5.5 Global trade: "The level playing field"

Thus, there is now growing awareness - as exemplified by the intentions in UK/DFID 2000 and in World Bank (2001b) and by the global commitment to International Development Targets - that *globalization of trade* can and must be made to work for the poor and hungry, and that elimination of poverty is in the interests both of developed and of developing nations. This awareness extends among various well-motivated governments, agencies, and civil-society groups - including the "faith groups" in whom poor people have highest confidence.

Moreover, some developing-country governments, and their agricultural and commercial sectors, consider that their countries' *food-security* interests and their comparative advantages are best served by policies of *food self-reliance* (ability to produce or purchase all required food) rather than of *food self-sufficiency* (ability to produce all required food). Other countries, however, including China, the populous countries of South Asia, and non-petroleum-producing countries especially, consider that "a large degree of food self-sufficiency is desirable to ensure food security" (FAO 1998b).

But all developing-country - and others' - opinions are unanimous and justified in insisting that global trade must be conducted on *a level playing field* - implying that global trade must be open, equitable, accountable, and rules-based, while allowing country-specific choices within those rules.

The benefits of agricultural trade in lessening poverty and food insecurity are that international trade promotes the general economic and income growths within a participating nation that are necessary to enable pro-poor and pro-equity and pro-employment policies to achieve their intended objectives. FAO (2000i) suggests that international agricultural trade can augment national domestic food supplies and lessen their seasonal and their year-to-year variabilities, and can foster economic growth and profitable product specialisation.

Conversely, there are attendant risks, well formulated in ADB 2001a, of uncertain supplies and of variable prices and the lack of resources wherewith to pay those prices. And particularly there is risk (FAO 1998b,

Annex 1) that international-market prices for cereals are likely to increase - though the experience of 1999-2000 may in the near term gainsay this forecast.

Moreover, within countries, trade liberalization shall create both "gainers" and "losers" among regions, among sectors, among producers, and among consumers. Explicitly, IFAD (2001) cautions that in countries with high levels of inequality the benefits of trade liberalization are garnered by the rich - through abuse of special-access privileges - with minimal benefit to the poor.

The level-playing-field concept requires that there shall be social and economic "safety nets" wherewith to protect and assist the "losers". Such WTO-compatible safety nets - which shall require resources - include state procurement and private-sector "futures" contracts for commodities at guaranteed prices, subsidies (not crop-specific) for credit and inputs and training, and "Green-Box" general services. Such services include food aid and buffer stocks, irrigation and market (including land-market) and other rural-infrastructural supports, phytosanitary and food-quality services and communal pest management, agricultural and veterinarian research/extension, decoupled income and insurance support, and export prohibition.

That the present WTO "playing field" is not level, particularly for agriculture, is manifest in several instances - instances which feature both developing and developed nations. For *developing* rice-growing countries, and despite the fact that the ASEAN and SAARC regional groupings have been operational for many years, the tariffs and disincentives to within-Asia international agricultural trade are considerable. Thus the South Asia Free Trade Area and the South Asia Preferential Trading Agreement (each within SAARC) and the Asian Free Trade Agreement and the Common Effective Preferential Tariffs (each within ASEAN) generally exclude agricultural commodities and many agricultural products. Strong barriers to agricultural trade thus persist within those trade groupings.

Additionally, there is minimal synergy between regional groupings. Moreover, Asian countries are often competing with each other to export similar ranges of commodities to the industrialized countries. Also, within some Asian countries, vested interests, of producers or of labour, are often successful in opposing the liberalization of agricul-tural trade; and as Singh (2001b) cautions: "trade-liberalization and food-security policy platforms are in many developing countries not well-defined".

However, it is *developed-world* trading con-straints that most impact on the rice-growing countries' agricultural exports and on their farm families. Thus, notwithstanding that the General System of Preferences (GSP) intends that developed countries shall provide non-reciprocal preferences to developing countries, many developed countries do confront developing-world agriculture with formi-dable tariffs and own-farmer subsidies, and with unjust phytosanitary and quarantine restrictions. FAO (2000i) reports that OECD countries operated tariffs (in 1995) on developing-countries' rice, wheat, and maize at the rates of 89, 94 and 90 percent. However, the EU has announced its abolition by 2009 of its tariff on rice from developing countries.

Moreover, the world-average tariff for *non-agricultural* products is 4 percent: for *agricultural* products it is 40 percent. UK/DFID (2000, quoting EU sources) estimates that if tariffs, both of developed and developing countries, were decreased by one-half, then developing countries would in aggregate gain US$ 150 billion (B) - about three times greater than the total OECD development-aid flows.

In terms of *subsidies*, the developed-world farmers and the developing-world farmers are clearly on different playing fields: FAO (2000i citing OECD 1996) reports that at 1995 the transfers, *via* export subsidies and otherwise, to each full-time-farmer-equivalent amounted to US$ 19 600 in the European Union, to US$ 29 200 in USA, and to US$ 32 800 in Japan. These transfers per farmer vastly exceed the total of income and subsidies received by any deve-loping-country rice-farm family (GNP / per person is listed in Table 14). OECD farm-export subsidies in aggregate at 1995 were about US$ 360 B - seven times the total of OECD development assistance.

Developing-world farmers have concern also, as expressed in a late-2000 Forum of the ASEAN Poultry-Producers' Association, that in addition to export subsidies to compete against local producers in developing-country markets, developed-world exporters may be resorting to unfair labelling to win market share. More encouragingly, FAO (2001c) reports that WTO procedures have facilitated increased use of anti-dumping and of countervailing duties on meat (including poultry meat) - though not specifically in Asia.

3.5.6 Global trade: industrialized countries and aid for developing-world agriculture

It is particularly noteworthy that several developed-world (industrialized) countries are substantial exporters of *agricultural* and of non- agricultural products to developing-world countries - including Asian countries. In aggregate, about 20 percent of all EU exports, and 40 percent of all USA exports, and 50 percent of US *agricultural* exports, are bought by developing countries.

The importance of these exports to the industrialized-country economies was highlighted by the 1997-98 East-Asian economic crises. Thus, IFPRI (1998c) estimates that, at 1998, US exports, including agricultural exports, to Asia decreased from US$19 B to US$5 B, and that there were similar impacts on the EU and on the Australian economies. EU and USA cereals exports each decreased by 7 percent (IFPRI 1998b). Similar effects may be expected as a consequence of the terrorism of 11 September 2001.

IFPRI (1998c) also calculates that each US$ 1.0 increase in developing-world farm output results in an additional US$ 0.73 of imports - of which US$ 0.17 are agricultural imports - pre-dominantly from developed countries. Such increase in developing-world farm output concomitantly increases rural employment - particularly women employment - and helps lessen poverty.

IFPRI (1998c) correspondingly rationalizes that - for all concerned - *aid for agriculture* is much preferable both to food aid and to crisis-relief aid, and that developed-world governments therein have a crucial role and responsibility. It is thus encouraging to recognize the mutuality of interest between developing-world agriculture and a major developed-world agricultural agency - the Foreign Agricultural Service (FAS) of the US Department of Agriculture. Within its many activities, FAS includes the management of international agricultural *financial assistance programmes.* Such programmes (FAS 2000) are undertaken towards the FAS Mission of "Serving US agriculture's international interests by expanding export opportunities for US agricultural, fish, and forest products, and by *promoting world food security"*.

Thus, overall, and despite concerns for tariffs and subsidies, UK/DFID (2000) and ADB (2001a) counsel that the General System of Preferences (GSP) affords the most appropriate route whereby the developing-world farmers can increase their share of global agricultural markets and maintain or increase their share of their domestic markets. Correspondingly, the World Bank (2001b) proposes a seven-point "holistic" strategy wherewith developing countries can be assisted to access the benefits of globalization and to manage the attendant risks.

Relatedly, UK/DFID (2000) recognize that the GSP is difficult to comprehend and operate, and that some countries have cultural anxieties concerning the WTO. It recognizes also that many smaller countries lack the human resources wherewith to participate effectively in the GSP and WTO, but notes that the developing countries command a substantial majority in the WTO and its committees, and that there is an Advisory Centre on WTO Law that assists poor countries to present cases under the WTO Dispute-Settlement Procedures. Committees of particular importance to developing countries include the Committee on the Provisions of the Technical Barriers and Trade (TBT) and the Committee on the Provisions on Application of Sanitary and Phytosanitary Measures (PSP). UK/DFID therefore recommends programmes of technical assistance and training to enable the developing world to use its collective strength to achieve desirable modifications of the GSP and WTO procedures - and to "level the playing field".

Within the Asian rice-growing countries, agricultural trade is variously constrained on both the supply side and on the demand side. On the supply side - and excepting the consistently effective exporters India, Malaysia, Pakistan, Thailand, and Viet Nam - the constraints of increasing population and of domestic food demand, and the historic low level of investments for commodities other than rice and wheat, have determined that despite some comparative advantages few of the seventeen rice-growing countries can consistently produce marketable surpluses of export quality - either of food-crop or of livestock products. Moreover, prospective exporters lack supports of export credits, of rural infrastructures, and of working / investment capital - against which there are more-attractive investment options. On the demand side, and for exports to developed or developing countries, the major constraints comprise tariffs and subsidies, some importers' discriminatory preference for particular suppliers, and the lack of low-cost distribution channels for small-volume producers.

[FAO (2000a) through its Divisions for Commodity and Trade, Policy Assistance, and Research, Extension, and Training has expertise, mandate, and ongoing activities - with training courses and manuals for TBT and PSP - to assist member countries to identify and address their various agricultural-trade concerns and opportunities. One of

the five FAO Asia-Pacific-Region integrated programme thrusts features "World Trade Organization: Capacity building, multi-lateral trade, and an enabling policy environment".]

4. Strategic considerations

The three foregoing sections of this document have introduced and quantified - by region and by rice-growing country - the several requirements, opportunities, and constraints that shall determine the extent to which Asia's rice-based livelihood-support systems shall be able during 2002-2015-2030 to lessen hunger and rural poverty. Drawing upon those foregoing sections, this present section addresses *strategic* aspects - of remoteness, water availability, crop nutrition, yield gaps, natural resources, and human wellbeing. These aspects are those that can help guide national governments in formulating prospective interventions to improve food security and rural livelihood. And can help particularly to formulate interventions that could be implemented effectively in partnership with FAO and with other agencies, and with the intended riceland beneficiaries. Interventions might be associated, particularly, with the FAO-assisted Special Programme for Food Security and with the supportive FAO initiative for Priority Areas for Inter-disciplinary Actions.

4.1 Remoteness

4.1.1 Remoteness and persistent poverty

Within and among countries, *remoteness from conurbations and markets* correlates with poverty (UK/DFID 2000 Figure 5.2, quoting Galup and Sachs; refer also ADB 2000a Footnote 13, and Dixon *et al* 2001). IFAD (2001 Box 5.1) suggests that persons who are remote from markets suffer a lack of understanding of market mechanisms in addition to suffering lower incomes and lesser access to consumer goods and to opportunities for assets accumulation.

In rice-growing countries, remote areas are often the areas with less-productive soils. They are likely also to have below-average endowments of other natural resources and of human and social resources - including health and education services. Such areas include many of the *rainfed*-lowland and *rainfed*-upland and *rainfed*-floodprone/swampland (as distinct from the irrigated-lowland) rice-farming systems. The alleviation and eradication of poverty in remote rice-growing areas is thus beset with difficulty.

Additionally, there is evidence from China (FAO 1998b Annex 3) that "there is *persistent poverty* among 50 million persons dwelling in remote, upland areas". Similarly, if the 1995-1998 farm-household-poverty percentages indicated above (from Singh 2001a) are real and not artefactual, they also may indicate that in India too there is a substantial and persistent population of remote, upland-dwelling poor.

[FAO's Medium Term Plan (2000a) is mindful of this concern for persistent poverty, and correspondingly includes specific and expanding activities on agriculture's contribution to poverty alleviation and to rural development in remote areas.]

To combat poverty in these remote rural upland areas, improvement of infrastructure and services, including financial services, is a pre-requisite (ADB 2000a, World Bank 2001a). There is need also (Dixon *et al* 2001) to provide specific programmes of farming-systems supports – but within integrative programmes of technological and social interventions. IFPRI (2000b) suggests that these upland farming systems might realistically comprise upland-rice-based agroforestry systems of higher than current productivity. FAO (1999b) explains that there are proven (SARM) systems that are both resource-conserving and economically productive. Similarly, ADB (2001b) affirms its priority support to SARM-type activities, with their incidental contribution to the dependability of irrigation supply to the downstream ricelands and hence to food security and livelihoods. Such programmes shall have high cost per beneficiary, but such cost may be counted as part of the cost of lessening rural-urban migration and of sustainable management of natural resources and heritage - and of lessening hunger and poverty.

[In which context, it is pertinent to note IFAD's (2001 Table 2.8 and text) discourse on the mismatch between aid provision and poverty incidence, and to recall UK/DFID's (2000 Figure 7.3, quoting World Bank) listing of the 1998 flows of development aid per ***poor*** *person:* ***US$ 950/person for the Middle East and North Africa, US$ 30/person for East Asia, and only US$ 10/person for South Asia****.]*

4.1.2 Investment for remote areas

The *rainfed areas in developing countries,* including rice-growing countries, are forecast (IFPRI 1998a) to be one of the sources of the increases in *feed grains and oil seeds* that shall be needed to support the 2002-2020 expansion in the livestock sectors. Resources - including *infrastructural* resources - shall be needed in those rainfed areas to facilitate these increases in feeds supplies, and also to facilitate increases in food production and in enterprises. IFPRI (1999b), in relation to India, but perhaps more-widely applicable, and IFAD (2001) opine that for infrastructural investments, the marginal rates of return are often higher for rainfed than for irrigated agriculture. IFPRI (1999b) further opines that provision of infrastructures in rainfed ecozones brings twin benefits - of increased production and decreased rural poverty.

Connectedly, and in relation to the interactions of agricultural production and rural-employment / income generation, FAO's (1998a) analyses for India and Malaysia, and ADB's analyses (2001a Chapter II Box 3, quoting various sources) for Bangladesh, Indonesia, Pakistan and Thailand, each demonstrate that a 1.0 percent increase in agricultural-output value results in a 0.5 - 1.0 percent increase in the outputs of the associated non-farm sector. This "multiplier effect" operates both in irrigated and in rainfed ecozones - provided that the human-population densities and the infrastructures are sufficient.

We here anticipate later sections of this document to suggest that for the Asian ricelands there shall be need for interventions, including policy interventions, for both the *rainfed* and the *irrigated* systems. Interventions in *rainfed* ecozones shall expect to lessen rural poverty and rural-urban migration. Interventions in *irrigated* ecozones shall help produce much of the increases in food supplies that shall be needed to ensure food security and adequate nutrition - both for the rural hungry and also for the urban hungry.

4.2 Water and irrigation

4.2.1 Effective use of water

Increases in *irrigation-water-distribution/ allocation efficiency* and in *field-level water productivity* and in *economic efficiency* of water use, and in irrigation's interactive contributions to fertilizer-use efficiency, are thus necessary and indeed feasible (ADB 2001c, IFAD 2001). Chapter 3.4.2 introduced the technical concepts of (irrigation-)water *efficiency* and *productivity.* IFAD (2001 Box 4.10) describes how the concept of economic efficiency of water use quantifies the *added value* of applied irrigation.

Recalling that *water productivity* quantifies the amount of produce generated per unit of water (including rainfall) received in the farmer's field, it is apparent that such *productivity* is influenced strongly by many factors other than the farmer's water management. Thus, factors such as a higher-yielding cultivar, increase in fertilizer application and/or efficiency, improvement in pest control, and a more-favourable-than-average solar irradiance regime, can each increase the production per unit of received water without any change in field-level water management. Quantification of the effect of improved field-level water management thus needs to be accomplished through analyses of single-factor productivities.

It is here pertinent to report that some irrigation systems - as in parts of India and Pakistan - were conceived and designed to satisfy part only of the rice-season crop-water requirement. They are essentially "protective systems" that provide, particularly in water-short years, an equitable distribution of such water as is available (FAO 1997a: Molden and Makin). Increasingly such systems are being augmented by farmer-owned tubewells.

Opportunities and methodologies do exist (Guerra *et al* 1998, FAO 2000a and 2000c) to improve both water-distribution/allocation efficiency and field-level water productivity by rice and non-rice crops. Such improvements provide opportunity to expand the land area serviced by an irrigation facility. An appropriate monitoring of water-productivity can be achieved in terms of crop production per volume of applied water: (t of produce) / (m3 of water) - analogous to t / (ha of land); or, as (kg of produce) / (kg of water) - analogous to (kg of grain) / (kg of fertilizer).

These measures of efficiency can be applied (Molden 1997) for an individual field, crop, and season. Adapting from Guerra *et al* (1998, citing various sources) we here indicate that *field-level water productivity* for irrigated rice in Malaysia and the Philippines ranges from 0.03 to 0.05 kg grain / 100 kg water (rainfall plus

irrigation). FAO (2000c) correspondingly indicates an aggregate value, for irrigated and rainfed-lowland rice, of about 0.03 kg grain / 100 kg water. These values may be compared with 2 000 kg grain / 100 kg fertilizer-N.

More strategically, this methodology (Molden 1997) for measuring efficiency can be applied also for an entire irrigation system, or for a complete river basin incorporating multiple irrigation systems. When applied to a single irrigation system, the methodology may be used for an individual crop and season, or for a whole farming year and its various crops. It can thereby capture the effects of water re-use - when water that has percolated through fields *higher* in the system is used in *lower-elevation* fields, or when drainage water collected from lower fields is pumped ("re-cycled") back to the conveyance canals at higher elevation.

Correspondingly, for a river basin, the methodology can quantify the benefit - as a water input to a *downstream irrigation system* - of water draining from an *upstream system.* However, FAO 2000c cautions that the required operational data may not be available. Nonetheless, at basin and system scale, the methodology can help determine any increase in total irrigated area that results from improvements in system or in on-farm management.

Irrigation facilities for rice-sequence cropping usually comprise a river-diversion structure, or sometimes a cross-valley dam, that facilitates the gravity-induced water flow along lined or unlined canals to bunded fields for which the aggregate area may be as little as 100 ha or as large as 100 000 ha or more. In some ecozones, powered lifting of river water and of groundwater, *via* deep or shallow tubewells, services a large fraction of the irrigated-rice area: about one-half in China and in India, and about five-sixths in Bangladesh (FAO 2000c).

Encouragingly, IFAD (2001) reports - also for Bangladesh - that poor *landless persons* have been able to purchase small-capacity low-lift tubewell pumps and, through labour-intensive endeavour, to use them to deliver and sell water to smallholders. In turn, these smallholders - in consequence of their more-intensive usage of high-yielding cultivars - derive greater benefit from irrigation applications than do large-scale farmers.

For *tubewells,* there is in Bangladesh - and perhaps in other rice ecozones - sufficient groundwater to allow intensification of current networks. Conversely, excessive abstractions have in some ecozones *lowered groundwater levels* to such extent (FAO 2000d reports 1.3 m / ann lowering in north-western India and in China) that pumping costs have increased considerably. And in other ecozones, as in Indonesia, some existing tubewells can no longer access the groundwater supply, and programmes of replacement and rehabilitation are needed. Thus, IWMI (2001) reports that an India consortium of NGOs assists villagers to site, construct, and maintain low-cost water-impoundment structures from which impounded water percolates to recharge underlying aquifers.

Other detrimental results of inappropriate irrigation (IFPRI 1995c; IRRI 1997; FAO 2000d) include water-logging (6 Mha in India) and soil salinization (1 Mha in Pakistan) and nitrate and pesticide pollution of groundwater.

[Pertinently, there may for some irrigation systems and their river basins be proposals that water-distribution/allocation efficiency should be increased by lining with impervious materials the major water-distributing canals so as to lessen water seepage and percolation. However, such percolated water may have been contributing to the aquifers and ground-water that are accessed by downstream tubewells. And the farmers dependent upon those tubewells may be poorer than the farmers receiving gravity-flow water through the irrigation system. In terms of regional poverty alleviation, it shall therefore be appropriate to conduct technical/economic analyses to determine who and how many shall be the gainers and the losers from canal-lining programmes.]

4.2.2 Field-level and water-catchment aspects

For both the rice, whether transplanted or direct-seeded, into puddled or non-puddled soil, and for the non-rice crops, the irrigation water is usually applied by inundation / submergence, or by furrow-flooding to non-rice crops, within the bunded field. The puddling process, including its preparatory land-soaking / softening, for the first (post-dry-season) rice requires much water - most of which flows through soil fissures to recharge the local groundwater. This water flow may be lessened, by perhaps one-third, by a shallow tillage at the conclusion of the previous season's cropping. Conversely, it may be increased appreciably if, at the onset of

the rice season, resource-poor farmers perforce make non-productive applications of water while awaiting the availability, for puddling operations, of draught animals and hand-tractors or/and of labour.

Dry seeding of rice into non-puddled soil - analogous to barley or wheat seeding in temperate agriculture, or to upland-rice seeding - is possible; but resultant plant populations and grain yields are usually inferior to those from puddling / transplanting procedures. However, this dry-seeding technology, with corresponding weed-management methodology and herbicides, and perhaps with early-vigour and herbicide-resistant rice cultivars, may expect to become more effective by 2020. Dry seeding into non-puddled bunded fields may by 2030 be especially effective if "aerobic-rice" cultivars have then achieved yield potential comparable to the current new-plant-type and hybrid cultivars.

Dry seeding could thus permit appreciable savings of water at field level - and perhaps also at irrigation-system and river-basin level - notwith-standing that the beneficial effects of percolated-water re-use might be diminished. In Texas (USA) research, a dry-seeded rice crop yielded substantially less than a crop wet-seeded into puddled soil. Conversely, in a water-short year in Malaysia, extensive dry seeding saved sufficient water at irrigation-system level that farmers were enabled to achieve some rice yield, against an expectation of zero yield if water for rice-puddling/transplanting had been awaited.

Wet seeding of rice - in which pre-germinated rice seeds are sown into / onto wet puddled soil is - because of rising labour costs and an availability of appropriate herbicides - increasingly practised in some rice ecozones. Farmers adopting this methodology generally shorten the duration of their pre-puddling land soaking, such that the number of days during which soil-submergence water is retained in the field is decreased by about one-fourth (Malaysia and Philippines experience). There is a corresponding decrease in rice-season water requirement: FAO (2000c) reports a one-fifth to one-fourth water saving, and also a very considerable rice-establishment labour saving, in China. For both dry-seeding and wet-seeding procedures, there are stringent requirements for land levelling - for which laser-assisted methodologies are available; there is need also for effective drainage and rigorous weed control: the latter likely to met by increased applications of herbicides rather than by labour-intensive hand-weeding.

[This oft-recurring concern for agricultural-labour shortage at a time when pro-poor strategies are equally frequently expressing anxiety for rural unemployment and urging labour-absorbing strategies is a ***conundrum*** *- and perhaps also a pro-poor opportunity. IFAD (2001) expresses strongly the views that "the rural poor are especially dependent on their labour power . . . that subsidies to labour-displacing tractors cannot normally be justified . . . and that the use of* ***rural labour*** *has social advantages, and its use is* ***not*** *a farm cost that researchers should strive to minimize." Thus, prominent among the benefits of any pro-poor programme must be the generation of rural employment - employment that is sufficiently remunerative, cost-effective, and drudgery-free as to counter the demand, originating from experiences of brief peak-period labour shortage, for worker-displacing technologies. With modern farming systems - and 100 years after Henry Ford - there must be labour-friendly ways to spread labour demand. Similarly, as Dixon et al (2001) suggest: there is need for research to improve productivity of labour - not only of land; and as (FAO 1999b) opines in relation to natural-resource management: taxes on labour should be repealed and replaced by taxes on natural resources.]*

At the micro-scale, *"rainwater-harvesting"* impoundments when located at higher elevation within individual farms - either rainfed, or at less-reliably-supplied locations within an irrigation system - provide a valuable and efficient water supplementation to lower-elevation fields during water-short periods. For aggregations of non-irrigated smallholdings, Indian and possibly other studies have quantified the benefits of a reasonably-assured supply of perhaps one-fifth of the crop-season water needs. Consequently, there is in India a national "watershed" programme of small-scale impoundments, often supplemented by stream-water diversion, to provide some degree of water security and hence food security to poorer communities.

For such impoundments, in India or elsewhere, the dependability of water inflow is determined by the water flow from the upstream watersheds. There is thus strong need for effective land, water, and vegetative-cover management within the upland forests and on the agroforested lands.

[Rainwater harvesting, and forestry and agroforestry, feature respectively in the activities ongoing in the Asia-Pacific Groups of the FAO (2000a) Land and Water Development Division and of the Forestry Department.]

Correspondingly, the World Bank (Plusquellec, in FAO 1997a, re Sri Lanka and southern China) and IRRI-IFAD (2000: Varma, re eastern India) describe the down-catchment progression - in catchments with or without major engineered irrigation schemes - of main reservoir, intermediate-size reservoirs, and community and on-farm ponds. The ponds serve not only as a source of water for crops, but also as necessary bathing and drinking pools for large livestock.

In rainfed systems, upland or lowland, there is often opportunity - though at a cost, which may be accounted as a cost of poverty alleviation - of using diesel- or electricity-powered pumps to transfer pond or reservoir water to higher-elevation fields. In some rice-growing uplands, there may be small areas of spring-supplied irrigation for terraced rice (Dixon *et al* 2001, re the Highland Mixed Farming Systems). And there may in some ecozones be opportunity to construct within-farm along-contour interceptor plots to accumulate and retain rainfall-runoff water: such retained water subsequently replenishes the root-zone-soil moisture for downslope crops (IRRI-IFAD 2000: Singh and Singh).

After *irrigated* rice is established, whether by transplanting or direct seeding, and provided the farmers have confidence in the reliability of their irrigation supply and of their herbicides and molluscicides, then without risk of rice-yield loss the farmers can decrease the water losses to seepage and percolation by forsaking, either for the whole season, or from panicle initiation onward, the continual retention of water above the soil surface, and instead maintain their soils at moisture-saturation without any overlying water, and thereby save one-half or one-third of their seasonal water use. Similarly, the Chinese procedures of "intermittent flooding" can save almost one-half of the post-establishment water requirement (IWMI 2000c, FAO 2000c).

A greater control of the rice-phase soil-water regime facilitates also a more-efficient management of *rice nutrition* - including the ensurance of sufficient moisture to allow P-uptake, and the lessening of N-losses by leaching and by the greenhouse-gas-producing processes of nitrification and denitrification. Moreover, for the succeeding *non-rice crop,* a less-wet soil at rice harvest permits a more-prompt establishment - especially beneficial in rice-wheat systems.

4.2.3 Irrigation-system modernization

For various *post-rice non-rice crops,* designs for any *new* river-diversion systems, and for *modernization* of existing rice-irrigation systems, might expect to incorporate features that facilitate the adoption of water-efficient technologies such as drip, spray, or sprinkler irrigation (using deficit irrigation - IWMI 2000c- as appropriate), and would include options to supply plant nutrients within the irrigation water.

In areas now or prospectively subject to salinization, designs would expect to facilitate also the conjunctive use of sweet and brackish waters. Correspondingly, for both rice and non-rice crops, there could by 2015 (or 2030) be adaptation within Asia of the water-efficient centre-pivot irrigation facilities that are used successfully in Brazil for rice-soybean sequences - though IFAD (2001) cautions that centre-pivot systems may be labour-displacive.

As reasoned in FAO (2000c), economic forces shall require the adoption of these various water-efficient technologies; and though the current generation of farmers understandably has misgivings about the difficulties of managing complex systems, during future decades the succeeding better-educated computer-literate generation shall be expected to confront and overcome these difficulties.

The *modernization* of an existing irrigation system comprises a complex of undertakings (FAO 1997a, 1999g). It encompasses much more than the restoration of the system to its original state ("rehabilitation"). It is a "transformation" process of technical and managerial upgrading and of associated institutional reforms that creates a system superior to that originally constructed. It is likely to incorporate corrections and improvements to the original design, particularly in relation to drainage shortcomings and to operational practicalities, and to have flexibility to respond to future changes in the clients' needs.

The process is expected to engender in the system managers a sense of service and accountability to those clients (FAO 1997a: Burt). And for those clients, there are consequential requirements for changes in agricultural practices and in procedures of costs recovery. These several aspects of irrigation-system modernization are featured in the FAO-facilitated Special Programme for Food Security.

Overall, the modernization process is conceived as an integration of actions *"to strengthen hard-ware, soft-ware, and human-ware"* (FAO 1999g). The process thus has a justified emphasis on *training* for the various participants and stake-holders. However, there are worrisome shortages of experts and consultants able to provide the required integrated training, including its required emphasis on non-steady flow, and able to raise awareness of the many technologies that are already available to meet irrigation-system short-comings provided that correct diagnosis and prescription are made. There may also be need (FAO 1997a) for strengthening the available library of design/procedural guidelines and manuals. To help strengthen the corps and capabilities of experts and consultants and to provide reference materials, FAO has helped design a specific Training Programme for Irrigation Modernization (FAO 1999g: Burt).

The economic returns to irrigation-system modernization can indeed be substantial - notwith-standing that returns to the original investment in the system may have been disappointing. Moreover, for a system that is in need of rehabilitation, the additional cost of modernization is relatively small. However, some existing systems may not be amenable to modernization (FAO 1997a: Ooi, Facon). Programmes of irrigation modernization must therefore be conceived within a national strategy, for which Wolter and Burt (in FAO 1997a) suggest a procedural model. Crucially, the World Bank (1994, quoted by Guerra *et al* 1998) cautions that modernization will be ineffective unless accompanied by accountability, by strengthened system-management capability, and by the incentive of allocating to system maintenance the water-use revenues.

4.2.4 Irrigation-system maintenance and irrigation-user groups

Those programmes of *maintenance* may for many long-established irrigation systems be inadequate to sustain water-distribution/allocation efficiency: irrigation agencies often lack the budgets to finance such maintenance, and the farmers lack the incentives to undertake the work. The outcome is usually that irrigation supply, particularly at lower elevations, is unreliable - with the unfortunate consequence that farmers at all elevations adopt inefficient and inequitable water-allocation procedures as a protective measure.

However, there are some irrigation systems within which well-organized and well-supported *irrigation-user groups* do manage, operate, and maintain their irrigation facilities effectively. Conversely, Vermillion (1997, quoted by Guerra *et al* 1998) cautions that analyses of the effectiveness of users' management of their irrigation systems indicate "a mixed set of experiences, with govern-ment contributions declining, farmers' costs rising, and little evidence of increases in water productivity, crop yields, or farm income". FAO (2000c, quoting a joint World-Bank/FAO/IPTRID review) concludes that irrigation-user groups are effective only when endowed with substantive power.

FAO (2000c, quoting a joint World-Bank/OED review) suggests that *system maintenance* might be more effective if the structures and their operation are simplified - though such an approach may be counter to the long-term objective of flexible, high-efficiency operations and may not allow for the expectation that the future more-educated rice farmers shall be more technically proficient than their forebears. IFAD (2001) reports that increased education - formal or informal - does indeed correlate with better returns from irrigation.

The World-Bank/OED review suggested also that maintenance might be improved if divorced from system operation; such an arrangement might facilitate, as in China and perhaps elsewhere, procedures whereby the user group employs full-time maintenance staff. It might facilitate also procedures whereby pro-poor programmes, such as the Japan Fund for Poverty Reduction and the Japan Social Development Fund and the Popular Coalition to Eradicate Hunger and Poverty, could finance irrigation-system maintenance as a worthy medium-term food-for-work programme. There is thus reasonable expectation that the ongoing expansions of rural education and training, together with some external support, may by Year 2015 enable a larger proportion of user-managed systems, whether then modernized or not, to be effectively and profitably operated and maintained.

4.2.5 Irrigation: policy aspects

Overall, improvement in the effectiveness of irrigation-water use shall depend critically on the formulation and implementation of appropriate and country-specific *strategies and policies,* variously targeting the near term (2002-2005), the medium term (2006-2015), and the long term (2016-2030). The major issues for *comprehensive water-policy reform* were well presented in IFPRI (1995c), and are here adapted for rice-oriented river-diversion irrigation, with relevance perhaps for tubewell operators also.

An initial requirement is to formulate and regularize the rights and obligations of irrigation users - as individuals and / or as groups. *Rights* will include the right of access to water - possibly in combination with tenurial right to land and the right to influence the operations and maintenance of the irrigation system. There shall be *obligation* to contribute to that maintenance. There shall be a right to receive - and an obligation to accept - water from up-slope contiguous land. There is strong need also for *reform of irrigation agencies*, as a component of irrigation-system modernization, as urged by the World Bank (Plusquellec, in FAO 1999g).

Within individual irrigation systems, mechanisms to ensure equity among users at higher and at lower elevations are probably best set within realistic and equitable regimes of water pricing and of water markets and trading. Such mechanisms should be supported by the identification and abolition of unwarranted subsidies (ADB 2001c) and by a corresponding inception, as in India and perhaps elsewhere, of farmer-directed water-saving incentives. However, IFAD (2001) cautions that during the removal of subsidies, poor farmers shall be vulnerable, and that transitional arrangements shall be needed to protect them. Nonetheless, equitable water-pricing regimes might be expected to achieve unaided the objectives of increased effectiveness in water use, and to achieve simul-taneously a desirable expansion of the irrigation-system's service area. IFAD (2001) reports also that informal markets - for both ground-water and surface-water, and incorporating share-cropper arrangements - are functional in parts of South Asia.

ADB (2001a) advises, however, that the complexities of measuring and regulating the volumes of water delivered to individual farms and the considerations of water re-use shall constrain or delay the widespread adoption of water pricing and water markets. Similarly, there shall be need for external assistance to provide training and start-up resources to the irrigation users to equip them to initiate and operate water-pricing mechanisms, and a corresponding need to implement and to finance procedures of regulation and of monitoring. USAID and ADB, in partnership, already have experience of providing such assistance (FAO 1997a: Molden and Makin). However, it shall be expected (FAO 1997a: Facon) that adoption of the required reforms and mechanisms shall encounter opposition from various interest groups.

[To assist and guide these various types of operational, constructional, and policy initiatives, FAO (2000a) has a regular-programme entity for Agricultural Water-Use Efficiency and Conservation - incorporating a strong Asia-Pacific component, and with a strong commitment to the modernization of irrigation. Additionally, FAO is one of the co-sponsoring agencies for the international network on Information Techniques for Irrigation Systems (ITIS) and for the International Programme for Technology and Research in Irrigation and Drainage (IPTRID).

For the aspects of policy and of assistance to irrigation-user groups and of performance monitoring, there is perhaps a near-term opportunity for FAO and other partners to mobilize external resources to assist democratic governments to initiate controversial policies - for which the costs of interventions now are likely to be much less than the costs of remedies in Year 2015 and thereafter.

For the near and medium term, FAO and partners can also help obtain resources and initiate and strengthen programmes to disseminate available technologies to improve on-farm water-use efficiency for rice and post-rice crops. Such programmes could include pilot-project programmes, and water-management inter-ventions within the FAO-assisted Special Programme for Food Security. For the medium and longer term, support can similarly be provided to help formulate programmes of irrigation-system modernization and in evaluating options for major new facilities.]

4.3 Crop nutrition and fertilizer management

4.3.1 Crop nutrition and soil health

Aspects of *crop nutrition* and soil health were introduced in chapter 3.4.4. The *soils* for submerged-land rice culture have an enviable record of 5000 years of sustained usage. Only recently, in historic terms, and as a result of irrigation-facilitated rice-rice cropping, have previously-productive rice soils come under such pressures that some may have degraded - physically, chemically or micro-biologically.

However, soils of inherently low fertility have in recent decades been brought under rice cultivation - whether for non-submerged (upland) or for submerged-soil (lowland - including floodprone and swampland) rice. Understandably, these soil-constrained ricelands, which receive minimal purchased inputs, have low productivity and high potential to degrade further, and the farm families that depend on them are consequently poor and often undernourished.

Ameliorative (SARM) measures are known for some though not all of these pressures and constraints. Additionally, increase during the coming decades in rural off-farm employment, and in production from the more-robust lands (possibly through the deployment of appropriately-sanctioned genetically-modified cultivars) may lessen the requirement to cultivate the most fragile of these constrained lands - as happened in the industrialized countries.

Furthermore, for all rice-system crops - whether lowland or upland, constrained or non-constrained - environmental and economic considerations dictate that there must in future be an increase in fertilizer-use efficiency and a decrease in nutrient losses. Such fertilizer-use efficiency is usually monitored - whether during one season (for nitrogen) or averaged over several seasons (for phosphorus, potassium, sulphur, zinc) - as the proportion of applied nutrient that is retained by the crop, or by the ratio of mass (kg) of produce to the mass (kg) of applied nutrient.

Additionally, multi-season comparisons for individual fertilizer elements of the off-takes (net of retained residues) with the inputs (from all sources, including fertilizers) can quantify the trends in soil-nutrient status. For potassium, in particular, there is evidence (Dobermann *et al* 1996a) of rapid depletion in intensive rice systems, and corresponding evidence of economic benefit of appropriately-applied potassium.

For *micro-nutrients*, there has since the onset (*circa* 1960) of the "Green Revolution" been a progressive development of micro-nutrient deficiencies in intensively cropped Asian soils. The progression and multiplicity of some of the more-important among these deficiencies (as portrayed in Box 2) has been: zinc; zinc and boron; zinc, boron, and iron and manga-nese; and currently zinc, boron, iron, manganese, and sulphur. Encouragingly, there is increasing national-scientist awareness of the growth-promoting roles of micro-nutrient elements, and of the procedures wherewith to measure their effects. There is correspondingly in the national extension services an increased laboratory capability - provided in part by World Bank, ADB, and various bilateral donors - for measurement of these elements.

Additionally, many "micro-nutrient cocktails" are now commercially available in many rice-production ecozones. Dobermann and Fairhurst (2000) provide - for rice - an excellent guide for the in-field recognition, prevention, and treatment for deficiencies, and in some instances for toxicities, of nitrogen, phosphorus, potassium, zinc, sulphur, silicon, magnesium, calcium, iron, manganese, copper, and boron.

4.3.2 Fertilizer-use efficiency

Throughout the Asian rice systems, and during four or more decades, vigorous programmes of strategic and applied research and extension - involving many national and international agencies, sponsors, networks, consortia, and projects - have explored the processes of submerged-soil chemistry and micro-biology, and have quantified *fertilizer-use efficiency* in agronomic and economic terms. They have thereby helped formulate well-founded recommendations for on-farm practices and government policies appropriate to these submerged-soil regimes - whether irrigated or non-irrigated.

[For the rainfed-rice systems of eastern India, IRRI-IFAD (2000) provides an account of "best-practice low-level" fertilizer recommendations that are realistic in relation to the resource endowments of farm families in this high-poverty region.]

In most rice-producing ecozones - whether poorly or less-poorly endowed - the fore-mentioned practices, policies, and farmer-support services are complemented by laboratories - several of them incorporating a micro-nutrient measuring capability, by personnel and by procedures for soil and plant-tissue analyses. Additionally, there are for many ecozones locally-appropriate correlations between the laboratory analyses and the expected crop responses at recommended fertilizer rates - particularly for phosphorus and potassium.

Initially, these research / extension programmes determined, usually for irrigated rice, the nutrient efficiency and yield response for individual mineral-nutrient formulations, for individual plant- and animal-derived materials and residues, and for biochemically-fixed nitrogen. They often determined also the influences on those responses of the method/ timing of application, of plant-population density and geometry, and of rice cultivar - of which there is indeed an appreciable influence.

Subsequently, programmes of *integrated plant nutrition management* sought to identify and exploit, particularly for nitrogen, beneficial combinations of these various nutrient materials and management procedures and also of rice / nonrice-sequence inter-actions. Latterly, procedures of *integrated crop*

management seek to assist farmers to combine the procedures of integrated plant nutrition management with those of integrated insect-pest management and with best practices of land, water, weed, and disease management. Increasingly, these programmes are addressing the more-complex issues of nutrient management for *non-irrigated* rice systems and sequences.

4.3.3 Environmental concerns

In most irrigated ricefields, the proportion of applied N (usually urea-N) that is taken up by the crop is less than 50 percent, notwithstanding that there are farmer-appropriate techniques whereby this proportion can be substantially increased. The unused portion of the applied urea-N enters the aquatic and atmospheric environments.

Similarly, it is noteworthy that *animal-manure-N* is prone to substantial leaching loss - particularly in East Asia. Relatedly, Steinfeld *et al* (1997, citing Bos and de Wit 1996) report that about one-half of the N excreted by poultry and pigs is lost *prior to* land application. More encouragingly, recent analysis (IRRI 2001b) of 1989-2000 northern-Philippines data sets suggests that *rice-rice-sequence* pollution, by fertilizers and pesticides, of domestic water supply is much less than previously feared and does not currently pose a human-health hazard.

Box 2

Micro-nutrient deficiencies in Intensively cropped Asian soils: 1960 - 1970 - 1980 - 1990

Epoch	Micro-nutrients showing deficiency
1960s	zinc
1970s	zinc boron
1980s	zinc boron iron manganese
1990s	zinc boron iron manganese sulphur

(The World Bank, ADB and bilateral donors have provided laboratory facilities to measure these and other micro-nutrient elements)

Nonetheless, it shall be prudent to be mindful of FAO's (2000d) forecast that during 2002 to 2030 the rates of nitrogen currently applied to *rice* crops are likely to increase substantially. Forecasts for *vegetables* - sometimes grown in association with rice on rice farms close to urban markets - suggest future applications of up to 1 000 kg N / ha.ann. The fore-mentioned IRRI (2001b) analyses indicate that large on-farm applications of fertilizer and pesticide to post-rice *sweet pepper* have resulted in domestic-water concentrations that exceed the WHO safe limits.

Moreover, for medium-production irrigated-rice enterprises, economic analyses indicate that the 1996-98 cost of purchase and application (to rice) of fertilizer nitrogen - the least costly and therefore most-used of fertilizer elements - was typically 15 to 20 percent of total production costs, and only 5 to 7 percent of produce value. These values suggest that there is little on-farm economic incentive towards efficiency.

However, international urea-N and ammonia-N prices, reflecting world oil price, increased by about 20 percent between January/March 2000 and November 2000/January 2001. Thus, although prices paid by farmers in South and South-East Asia are often governed by domestic policies and not by international supply / demand, a continuing and sustained increase in world oil price may eventually result in farm-level prices that encourage N-use efficiency. Additionally, there shall probably be medium-term pressures to impose environmental pricing on N-materials.

It would thus be prudent, on environmental concerns, to identify, develop, and popularize procedures of N-fertilization for rice systems that are both *farmer-acceptable,* utilizing incentives if necessary, and efficient, and - in the case particularly of deepwater rice - practical. Moreover, as indicated by IFDC (1999) and IRRI-IFAD (2000), for marginal ricelands and farm-families - the less-favourably rainfed and floodprone lands with low fertility and few suitable cultivars and limited access to credit for inputs - procedures will differ appreciably from those for the better-endowed ecozones and families.

However, it is for all systems well-recognized that N-supply should match rice-N-demand. More-over, such matching can be achieved, in irrigated and in favourably-rainfed ecozones, through traditional broadcasting of urea into the field water, or incorporation into temporarily-drained soil, when such broadcasting is guided by

regular monitoring of plant-tiller number or of rice-leaf colour. Thus, IRRI (2001a) reports that 35 000 pieces of low-cost *Leaf-Colour Card* were distributed to Asian rice farmers during 1997-99. It is well known also that matching N-demand and supply, and consequent N-savings of 20-40 percent, can be accomplished by the use of controlled-release fertilizer-N (FAO 1999d, IRRI 2001a) or by the *deep placement* of briquettes (IFDC 1999) of fertilizer-N into the chemically-reduced soil layer.

However, because of the tedium involved, *deep placement* of briquettes is generally not accepted by *irrigated-rice* farmers - even in Indonesia, where suitable applicators were manufactured and distributed. But for *resource-poor* farmers in *remote* rainfed areas of Bangladesh, IFDC (1999) reports success using deep-placement technology in a programme involving easily-understood procedural guidelines and training, NGO collaboration, and production of briquettes (250 kg / hour, using machines costing $ 2 200) by local entrepreneurs.

For *upland* rice, fertilizer applications are usually minimal. Effective N-management is there best achieved through the *"good-land-husbandry"* procedures of sustainable agricultural resource management (SARM) which feature N-fixing legumes in agroforestry systems. IRRI-IFAD (2000) reports that rice and pigeonpea - whether in sequence or inter-cropped - constitute an effective combination in parts of eastern India.

4.3.4 Emerging technologies

For better-endowed ecozones and extension services, IRRI (2001a) makes available by Internet an on-farm *decision-support system* for rice; this system includes land, water, and pest management in addition to nutrients management. Similarly, for "mixed" crop-livestock systems, LEAD (1999) provides an internet-accessed *"decision-support toolbox"* wherewith to achieve environment-friendly management of livestock wastes. For *rice*-nutrition only, a palm-held-computer *decision-support tool* is in field use by agricultural extensionists in Thailand; and Dobermann and Fairhurst (2000) provide a *decision tree* wherewith farmers and extensionists can diagnose nutrient limitations from within-field measurements of yields achieved with and without individual fertilizer elements. For on-farm *in-situ* measurement of soil-nutrient concentrations, Dobermann *et al* (1994, 1996c, 1997) describe the use of resin capsules within procedures of site-specific nutrient management.

Precise quantification is needed for the N-uptake efficiency, for irrigated and favourably-rainfed rice, of the various component technologies that give promise of high N-efficiency. Such quantification is needed for major ecozones and for a range of application rates and for farmer-preferred rice cultivars and for both transplanting and direct-seeding systems.

Pertinent component technologies include the various categories of mineral N-fertilizers (possibly including polymer-coated controlled-release urea-N fertilizers), admixtures of mineral N-fertilizers with biologically-derived N-materials (especially poultry manure), leaf-colour-guided and tiller-number-guided N-application timings, foliar-applied growth regulators and possibly soil conditioners, and novel plant-population-density / geometry arrangements that can ensure sufficient rice grains at harvest to receive such amount of nitrogen as will generate a site/season-appropriate yield.

Vitally - there must be assessment also of the efficiency, and prospective N-application decreases, that would result from the *combination* of two or more of the more-efficient among the afore-listed individual N-technology components. Methodology to achieve the required high-precision assessments has been developed and validated for irrigated-rice systems in three rice-growing countries (FAO 1999d). This methodology includes field designs and computer softwares to undertake the required N-efficiency Mitscherlich-Model calculations both for *agronomic and economic* aspects. It is suitable, with appropriate training, for adoption by national extension services.

Additionally, FAO (1999d) has assisted Indonesian *rice* extensionists to design and validate a precise, impartial, and commercially-acceptable on-station methodology for evaluation and if appropriate, approval for commercial release, of fertilizer and/or growth-regulator products. The methodology can accommodate in any one season up to sixteen products / blends / compounds that have been developed / imported by manufacturers and distributors. Findings from these proposed quantifi-cations and evaluations shall be valid both for irrigated and for favourably-rainfed rice. For these lowland systems, the high precision in the proposed quantifications and evaluations is needed to ensure the validity and credibility of recommendations - both for

the farmers, and also for the commercial-fertilizer interests, whose confidence and partnership shall be needed in any large-scale implementation programmes. For the farmers, credibility requires also that there shall be functional and trusted procedures of fertilizer-quality regulation.

For post-rice *non-rice crops,* in all rice-system water regimes, fertilizer recommendations and practices may expect to derive from the world literature on the fertilization of crops grown on non-submerged soils.

[As with irrigation management, so with plant-nutrition and fertilizer management, FAO has expertise and mandate to assist member governments and their farmers and fertilizer cooperatives to obtain resources and to initiate near and medium-term programmes, including pilot-project programmes and training, to evaluate and disseminate available technologies to improve on-farm fertilizer-use efficiency for rice and post-rice crops. FAO has a regular programme for Integrated Plant Nutrition Systems (IPNS), and co-ordinates a long-established network to improve the management of constrained (problem) soils. Plant-nutrients management expectedly features within the FAO-facilitated Special Programme for Food Security and within the FAO (2000a) Medium-Term-Plan Priority Areas for Inter-disciplinary Actions.]

4.4 Yield-gap approaches

For rainfed and for irrigated crop systems, the long-established methodology of *yield-gap analysis* constitutes a proven mechanism wherewith extensionists can help farmers identify and perhaps remedy constraints to the production of rice and of non-rice crops. Correspondingly, there are procedures of productivity-gap analysis (Steinfeld *et al* 1997) wherewith to diagnose constraints to livestock production.

4.4.1 Yield-gap methodology

The field-crop yield gap is generally defined (FAO 2000c 2001f, quoting De Datta 1981 and other sources) in terms of *two components* that together quantify the difference between a representative (usually average) on-farm crop yield and the "potential yield". The potential yield is usually measured in research / extension trials using the most locally-suitable cultivar at optimal plant population and crop-establishment date and using maximal (uneconomic) levels of inputs.

However, the *physical* conditions of cloudiness, temperature, growing-season duration, rainfall / irrigation sufficiency, and soil (possibly constrained) may differ as between the "average" farm and the research / extension site. Moreover, efficient farmers apply cost-effective, and not maximal, levels of agro-chemicals and other inputs. There is thus a *realistic attainable yield* that efficient farmers can expect to achieve.

The difference between this attainable yield and the potential yield constitutes the first of the two yield-gap components. It cannot be lessened by supportive on-farm interventions. Any increase in attainable on-farm yield must depend on increase in yield potential.

The second component of the yield gap - the difference between the representative on-farm yield and the realistically attainable yield - is however amenable to remedial interventions. This component quantifies the yield-constraining effects of *institutional* factors and of various *biological* and *socio-economic* factors - including sub-optimal crop- and resource-management.

For irrigated and for rainfed (including upland) rice, these factors include (FAO 2000c: Siddiq, Duwayri *et al*, Papademetriou, and other contributors, FAO 2001f): low-vigour and infected seeds and insufficiency of seeds of recommended cultivars; sub-optimal plant population and pre-harvest lodging; unbalanced and insufficient application of plant nutrients and persistence of correctable soil toxicities and micro-nutrient deficiencies; weeds, pest insects, diseases (viral, fungal, bacterial), molluscs, and rodents; lack of mechanization, and of peak-period labour, and of draft and water-pump power; delayed access to agronomic and financial inputs; and uncertainties of prices, markets, and rates-of-return.

Additionally, yield gaps may persist because of farmers' lack of technical knowledge, and in some countries because of insufficient institutional supports to yield-gap-directed interventions. These supports include the ecozone characterizations necessary for recognizing the opportunities to combat the yield gaps. Correspondingly, sub-optimal but remediable post-harvest operations contribute to a *profit gap* that impacts adversely on farm-family and community livelihoods.

The *physical constraints* of soil, rainfall, cloudiness, temperature, and growing-season duration generally cause greater loss of production (whether of rice or of non-rice crops) than do the *biological* constraints of

seed quality and weeds, insects, pathogens, and other pests. Thus, as is cogently reasoned by Singh (1997), yield-gap analysis should be conducted for individual ecozones, rather than for whole countries. Correspondingly for *socio-economic features*, the major production determinants of land, water, labour, and working capital, and the aspects of inputs' costs and supply system and of outputs' prices and markets, and of risk and rates-of-return, shall vary within countries to such extent as to require ecozone-level analyses.

The prospective power of well-conceived and well-planned programmes of yield-gap analysis / intervention is illustrated (FAO 2000c: Lacy *et al*, Duwayri *et al*) by the Australian "Rice-Check Package" (and of its predecessor "Wheat-Check Package") and by the corresponding and evolving rice-production packages of China ("Seven Techniques" and successors), Indonesia ("Insus" and successors), the Philippines ("Masagana-99" and successors), and others.

Both the farmer-participatory "Rice-Check Package" (a "Ten Ton per Hectare Blueprint", Lacy 1998) and the "Seven Techniques Package" present guidelines for land preparation, optimal sowing date with appropriate cultivar, high plant-population density, weed control, water management, and (in the Australian package) leaf-N-guided nitrogen management. The "Seven Techniques Package" contributed to four decades' of impressive rice-yield increases in China. For the "Wheat-Check Package", FAO (2000d) reports that between 1985/89 and 1995/99 this package helped increase farmers' average yield by about 23percent - from 6.8 to 8.4t/ha.

Each of these packages emphasizes that because it is not possible to predict which yield constraints shall occur in any particular crop season, *all* components of the package must be rigorously adopted. All these packages, and a similarly successful rice-directed Egyptian package, emphasize the necessity for intensive training, large-scale demonstration, and institutional support.

The "Rice-Check Package" (Lacy 1998) has the farmer-directed dictum: *Observe, Measure, Record, Interpret, Act*. The outputs from adherence to this dictum provide a crucial input to the farmers' participatory but extensionist-guided regular discussions, monitorings, and evaluations of their rice management and its achievements. An adaptation of the Rice-Check / Seven-Techniques "package" procedure is included among the candidate interventions, for both irrigated and non-irrigated rice systems, in Section 5 of this document.

Such a procedure could contribute strongly to the "Farming-Systems Intensification" component of the four-component Special Programme for Food Security (SPFS). Moreover, and in consonance with the ideas formulated in this sub-section, the conduct / interpretation of yield-gap / constraints analyses is the first of those four SPFS components.

Furthermore, location-specific adaptive-research investigations (such as those previewed in chapter 4.3.4) could and should be associated with the evaluation / strengthening of the "package" procedure that is expected to be undertaken within FAO's SPFS-supportive Priority-Area Inter-disciplinary Actions (PAIAs).

Crucially, the PAIAs are expected also to contribute strongly to the fourth SPFS component: "The Vertical and Horizontal Diversification of Agricultural Production". In which context, it is pertinent (IFAD 2001) that diversification and intensification are *complementary* procedures wherewith to increase farm income and entitlements; and pertinent also (Dixon *et al* 2001) that intensification can facilitate diversification. However, these procedures can succeed in raising smallholder incomes only if there is access to the necessary assets and markets.

That there is indeed potential for Asian rice-system farmers to derive substantial gain from yield-constraints analysis is manifest in the statistics (FAO 2000d) that for both rice and wheat the top-decile yields are about five times larger than the lowest-decile yields. Notwithstanding that those data were aggregated at national rather than ecozone level, there is nonetheless some likelihood that *within ecozones* a vigorous programme of yield-gap-driven interventions would help raise the lowest yields, which are probably the yields of the poorest farm families.

Moreover, in relation to food production and security, FAO (2000d) indicates that at 1995/97, and prospectively at 2030, and for both rice and wheat, the yields from the *large-scale producers* are only one-half of the all-farms top-decile yields. There is corresponding implication that yield-gap analysis may help identify opportunities to raise these large-scale-producer yields.

Thus, for *irrigated* rice, which occupies rather less than three-fifths of the Asian-total rice area (Table 5), Asian-average on-farm yield is now about 5t / ha - though notably above-average in North-East Asia, and

substantially below-average in some South and South-East Asian countries. The advent (by Year 2005) of rice cultivars with appreciably increased yield potential could expect to raise this average to 6t/ha.

Ecozone-specific yield-gap-driven interventions during 2002-2005 could by 2010 help increase this average somewhat further. Interventions might be particularly successful in those countries (Cambodia, Laos, India, Philippines, Sri Lanka) where current-average irrigated-rice yield is less than 4t/ha. Relatedly, Siddiq (2000 Table 10) indicates that among twenty Indian rice-producing states, the state-mean on-farm yield was on average only one-half of the corresponding experimental-trial yield, with the proportion ranging from as little as one-fourth to as high as four-fifths.

The irrigated-rice-yield losses result predominantly from water and soil constraints (IRRI 1997), for which technical and cost-effective solutions are available - provided that correct diagnoses are made. Thus, chapter 4.2.4 indicates some of the soil-constraint-amelioration options. Siddiq (in FAO 2000c) reports also that India's 1980s irrigated-area yield-gap analyses elicited worthy and effective institutional responses. Moreover, comparison of results from the Indian yield-gap surveys of 1987 and 1997 indicates that though improved cultivars raised yield potentials during that 10-year interval, yield gaps were essentially unchanged - indicating the validity and benefits of the yield-gap methodology.

4.4.2 Yield-gap approaches: rainfed-rice-system concerns

Concerns for the rainfed (non-irrigated) rice systems were expressed earlier in this document. For these rice systems, the yield-gap methodology is a particularly useful component in the identification of appropriate crop- and resource-management options. Correspondingly, for any rainfed-rice ecozone a preparatory and detailed and community-participatory analysis of the biophysical and socio-economic features is pre-requisite. These analyses determine the growing-season *("stable-rainfall-period" and its onset date)* and soil-suitability constraints and opportunities and the prospective profitability for candidate cropping systems and sequences. The analyses help, similarly, to specify the management options and the characteristics required for the cultivars of the proposed component crops - and thus may identify needs for cultivar development to match those characteristics.

In this context, and despite the encouraging feature that modern cultivars are being adopted in some rainfed ecozones, there are many other rainfed ecozones - notably the deepwater and the upland - for which only traditional, low-yielding, though sometimes high-quality varieties are available. Some of these traditional varieties indeed have such strong consumer appeal that support to farmer-participatory selection and breeding to increase yield potential while retaining the consumer-preferred traits may constitute (ADB 2001b) a cost-effective pro-poor investment. As IFAD (2001) emphsizes, farmer-participatory breeding is a worthy complement to formal research.

For the more-favourable *rainfed-lowland* ecozones, which comprise one-fourth of the Asian rice area, and are home to many poor people, current Asian-average rice yield is about 2.5t/ha. Improved cultivars and well-directed interventions during 2002-2005 might realistically be expected to raise rice yield in these ecozones to 4t/ha by 2010. Dominant constraints to rainfed-lowland-rice production result from diseases and pest insects, from shortness of rice-sequence growing season, from shortage or/and excess of water, and from soil toxicities and deficiencies.

The development of the required locally appropriate cultivars - for a wide diversity of ecozones - may expect to be accelerated by the identification of "dominant environments" that characterize substantial areas ("targets") of rainfed-lowland rice. For ten such "dominant environments", a reference cultivar has been selected, and internationally distributed, to facilitate the quantification of genotype x environment interaction, and hence to simplify the (local) breeding targets. Additionally, preliminary *hybrid-rice* materials are currently being evaluated (IRRI 2001b) in rainfed-lowland India, Philippines and Thailand.

The *rainfed upland* and the *rainfed flood-prone/swampland* ecozones each occupy about one-tenth of the Asian rice area. On these marginal and often remote lands, a large proportion of the populace is poor, undernourished, and lacking of infrastructural and social amenities. Rice yields in these ecozones are respectively about 1.3 and 1.6t/ha. In the flood-prone systems, water excess and shortage - and the difficulty of applying nutrients - are the over-riding constraints. In the uplands, rice yields are limited by soil-chemical constraints - exacerbated by erosion of surface soil, by drought, and by fungal (blast) disease, and weeds.

Rice-cultivar improvement perhaps offers the strongest option for achieving yield increases in the flood-prone and in the upland systems - including some prospective impact (by 2020) in the uplands from perennial rice, aerobic rice, and from C4-photosynthesis rice. The Asian Development Bank (ADB 2001a, 2001b) affirms its priority support for the development of cultivars for the less-favoured areas. For the uplands, agroforestry systems - alley-cropped, with shrub-legumes and/or with vetiver and other grasses - and other components of sustainable agricultural resource management (SARM) and of Integrated Land-Management Technology (ILMT) can facilitate soil stabilization, rainfall retention, nutrient recycling, and hence increased and sustainable yields.

However, in all three of the rainfed ecozone-types, production of rice and of non-rice crops is limited additionally by the economic risk associated with the unpredictability of the various biotic and abiotic constraints and stresses. In this latter context, FAO (1999b) emphasizes that in any SARM-type interventions the costs to be incurred by the participant farm families must be commensurate (allowing an appropriate "risk factor") with the prospective benefits; and those benefits must accrue to the implementing farm families, and not to off-site communities. Similarly, to encourage ILMT-type interventions, IFAD (2001) suggests that incentives may be needed - provided that the social benefits are substantial in relation to the costs. Dixon *et al* (2001) suggest that restoration of degraded uplands could be financed through food-for-work programmes.

4.4.3 Yield-gap approaches: rice-seed aspects

For all ecozones, the aspect of rice-seed quality and vigour merits specific mention. For various countries, various sources (e.g. FAO 2000c, IRRI 2001b) indicate that the use of quality seed confers a yield advantage of some 9- 15 percent; or inversely, that non-use of quality seed incurs a yield gap of 9 - 15 percent. Additionally - and importantly - quality seed also results in harvested grain of higher quality commanding a higher price. Nonetheless, only one-fifth of Asia's riceland receives high-quality seed - whether for lack of supply - perhaps a result in some ecozones (IRRI 2001b) of labour shortage - or for lack of demand.

Seed management is often the preserve of the female farm-family members. Seed-management training and micro-finance support to such farm-family members may thus constitute a highly cost-effective intervention. Such support might best be implemented in non-labour-constrained ecozones, and perhaps in partnership with NGOs, agro-supplies retailers, *academia*, and the local seed authorities. Previous FAO-assisted projects, such as TCTTI, provide models for such support.

In the non-irrigated ricelands, indigenous seed-management skills help maintain the *biodiversity* that is represented by the less-widely-grown rice cultivars. Thus in the rainfed parts of the Indo-Gangetic Plains, two-to-five, and sometimes as many as ten, different rice varieties - traditional and modern - may be grown within an individual farm (IRRI-IFAD 2000, quoting Kshirsagar *et al*, 1997). Procedures might be found, perhaps in association with the FAO programme entity "Alternative crops and cultivars" – wherewith to reward financially this endeavour in management of biodiversity and of its constituent seeds.

4.5 Forecasts for ricelands' natural (and climate) resources

Globally, during 2002-2030, agricultural environments shall experience increasing pressures as a consequence of the needs for increased productions of crops and livestock. However, these pressures shall almost certainly be countered by the advent of improved technologies and procedures. Correspondingly, the pressures on agricultural-system biodiversity and habitats are forecast to increase less strongly than in the past. Conversely, global agriculture shall itself impose increasing demands and pressures on the global environment - particularly the atmospheric environment.

For the Asian ricelands, the current status and trends in natural-resource endowments were introduced earlier. This present section considers the strategic implications (during 2002-2030) of those trends. It considers also the impacts - both by and on Asian rice-systems' agriculture and their natural resources - of the forecast changes in global and in Asian climates. Prominent among these strategic considerations are those of nitrogen emissions (nitrous oxide and ammonia) and of carbon emissions (methane and carbon dioxide), sea-level rise, changes in patterns of precipitation and temperature, the geographic separation of zones of arable and of intensive livestock farming, and the opportunities for carbon sequestration.

4.5.1 Gaseous emissions

For the *gaseous emissions*, FAO (2000d) suggests that agriculture (globally) might responsibly focus on lessening nitrogen emissions - which are forecast to impact more adversely on global climate than are the carbon emissions. Chapter 1.3.3 indicated that from global agriculture, including riceland agriculture and its livestock, *ammonia* emissions, which cause acid rain, are expected to double during 2002-2030. Moreover, the expected separation of intensive peri-urban livestock enterprises from the rural crops-based farming systems is likely to lessen the options for disposal of animal excreta to arable land, including rice-system land. There shall thus be need for policies, monitoring, and regulations enforcement to ensure that these excreta do not pollute the local ground and surface waters *nor* the global atmosphere. These needs are addressed in the fore-mentioned livestock-environment "toolbox" (LEAD 1999); they shall be particularly important in those peri-urban areas that experience large increases in populations of poultry, pigs, and cattle.

Nitrous-oxide emissions are forecast to increase x1.5 during 2002-2030 - though the increase in rice-crop emission shall expect to be much less than x1.5 in consequence of the forecast stabilization of riceland area and the expected development and adoption (prospectively with FAO assistance) of environment-friendly procedures of N-fertilizer management. Such procedures would expect to lessen also the release to the atmosphere of ammonia when urea fertilizer is broadcast into rice-field-submergence water.

Methane emissions from *global* agriculture are forecast (FAO 2000c) to double during 2002-2030. Livestock shall be the main contributor: there shall be consequent need for the management procedures presented in the LEAD "toolbox". *Rice-crop* methane emissions are forecast to increase much less seriously - in consequence of the development and deployment of rice cultivars that internally transmit to the atmosphere lesser quantities of soil-generated methane, and in consequence also of the adoption of more-appropriate ricefield water management.

4.5.2 Sea-level and air-temperature changes

Mean *sea level* is forecast to rise by about 0.2 m by Year 2030. The many coastal low-elevation ricelands would thereby suffer loss of production because of increases in soil salinity and perhaps in flooding. If by 2030 there are changes also, at low elevation, in river flows and aquifer recharges, the availability and quality of irrigation water for the coastal ricelands would be affected adversely. Moreover, low-elevation hinterland ricefields - as well as coastal ricefields - will expect to be at increased risk from typhoons and cyclones. For all elevations at mid-latitudes (including South Asia), *precipitation* is expected to decrease - with adverse effect for rainfed-rice systems (lowland and upland) and for aquifer recharge and hence for riceland irrigation.

Effects of increased *global temperature* are not expected to impact strongly on *rice* production. There may for all rice areas be some decrease in yield because of increased respiration, but that shall probably be compensated by increase in photo-synthesis resulting from increases both in atmospheric temperature and in carbon-dioxide concentration. In sub-tropical ecozones, there may be some increase in fungal and viral disease and insect-pest cool-season carry-over. However, for the sub-tropical Indo-Gangetic Plains, temperature increase is likely to bring adverse consequence (Singh 2001b) for post-rice *wheat* production. For sub-tropical rice-*livestock* enterprises, costs of animal housing may be lessened. For tropical-zone *livestock* in areas with decreased precipitation there may be increased heat stress and lessened production. The plant and animal *biodiversity* of ricelands is already much determined by human activity, and is consequently unlikely to be much affected by climate change, though there may be small effects on micro-organisms active in nutrient transformations, and on pollinators of rice-system crops.

4.5.3 Technologies and policies

FAO (2000d) suggests that technologies already exist wherewith to address most problems of pollution that do or will emanate from intensification of rice systems and from progressive global climate change. Moreover, the *average* effects of climate change (by Year 2030) shall be much less than the effects of economic and technical change. However, the tropical and sub-tropical eco-systems, and the poor communities dependent upon them - and who contribute least to global warming, shall be at personal and economic risk from increased frequency and severity of extreme events.

Ensuring that the ricelands do deploy environment-friendly and food-productive procedures shall require substantial efforts and resources from various national and international stakeholders. There shall be need for appropriate *policies* with attendant regulations and enforcement thereof. Notably, for many rice-growing countries there is need (UK/DFID 2000, ADB 2001a, IFAD 2001, World Bank 2001a, Dixon *et al* 2001, LEAD 1999) to identify and phase out those *subsidies* that encourage and reward environmental degradation and resource misuse.

Prominent among those environment-damaging subsidies (FAO 2001a; IFPRI 1999b, Singh 2001b) are those for fertilizer, water, electricity, credit, and livestock-feed concentrates. However, FAO 1999c and this document caution that small quantities of feed supplements and concentrates shall be necessary to raise productivity of smallholder livestock. IFPRI argues that the misguided subsidies should be redirected to promote organizational transparency and accountability and collaboration among public, private, and civil sectors of society.

Correspondingly, there is for some countries a continuing need to assist governments to review, and if appropriate repeal, anti-smallholder and anti-agriculture policies, and to initiate pro-rural and pro-smallholder policies that reward sustainable natural-resource management. Such pro-smallholder policies would expect to ensure equitable access to the resources of land, water, and common properties: the latter especially important to poor families as a source of fuel and fodder. ADB (2001c) and World Bank (2001a) emphasize the importance of good governance in addressing these several policy issues; ADB suggests also that the ADB-initiated sub-regional growth triangles could here assume an influential role.

Technologically, and predominantly in relation to irrigated systems, this document indicates that for rice-phase management there are environment-friendly and cost-effective procedures for water, fertilizer and pest management. For irrigated post-rice crops, CIMMYT (2000a) reports that no-till establishment of post-rice wheat can save 1000 m3 *water* / ha.crop, and by the lessening of tractor-fuel use and the avoidance of crop-residue burning can decrease by 13 t / ha.ann the release of carbon dioxide (CO_2) to the atmosphere. Generally, populations of soil arthropods may increase where minimum-tillage practices are adopted. CIMMYT reports also that its prototype bed-system post-rice-wheat seeder lessens the wheat's requirements for water, nitrogen and pesticides. Each of these post-rice innovations is cost-effective.

4.5.4 Carbon-sequestration and bio-fuel options

Chapter 4.5.1 indicated that lessening agriculture's N-emissions should have higher priority than lessening C-emissions. Nonetheless, agricultural *sequestration of carbon*, whether in soil or in standing crops, is a viable (Agenda 21 and Kyoto Protocol) procedure wherewith to counter CO_2-enhanced global warming. It is a procedure that can be adopted by rice-system farmers. Moreover, such adoption and the attendant financial compensation may be particularly attractive to farmers operating on constrained or degraded lands. These lands might include those affected by *salinity* - whether existing or induced by sea-level rise; such lands could sequester carbon in their soils at a rate of 0.3 t / ha.ann.

The degraded lands could include also the *fragile upland* ricelands, where appropriate carbon-sequestering crop / livestock systems could additionally help arrest soil and nutrient erosion - provided that land-rights issues are addressed (Dixon *et al* 2001). The industrialized-countries' procedures of deliberate and financially compensated "*permanent land set-aside*" might be adaptable for some of these fragile uplands - including their community-managed forest areas, and for areas for which alternatives to shifting cultivation are being sought (ADB *via* Dixon *et al* 2001 Box 6.8). Carbon sequestration in *soil organic matter*, which for post-rice crops can be facilitated by various procedures of conservation tillage, brings additionally the agronomic benefit of increased water-holding capacity and phosphorus availability - particularly important for upland soils.

It is thus pertinent that the carbon content of the annual global production of non-harvested *crop residues* (stalks, stubbles, roots) which could be incorporated into soil, and thereby insulated against oxidation to CO_2, represents about 2.5 Bt (billion ton) *carbon* /ann in 1995/97, with forecast to increase to about 4.5 Bt *carbon* / ann by 2030. Ranges (derived *via* FAO 2000d, quoting various sources) for the estimates and forecasts for the amounts actually or forecast to be sequestered *globally* are 0.7 to 1.2 Bt C / ann at 1995/97 and 1.2 to 2.2 Bt C / ann at 2030. Corresponding ranges for *East Asia* are 0.2 to 0.4 Bt C / ann at 1995/97 and 0.3 to 0.6 Bt C / ann at 2030, and for *South Asia* 0.1 to 0.2 Bt C / ann at 1995/97 and 0.2 to 0.4 Bt C / ann at 2030. Appropriate policies,

programmes, and incentives could almost certainly ensure that the totals of carbon sequestered at 2030 are close to - if not above - the upper values in these ranges.

Relatedly - though not a carbon-sequestering procedure - the large-scale co-ordinated growing of *Miscanthus sp.* or of *Pennisetum purpureum* (Napier or Elephant grass) as high-thermal-efficiency bio-fuel crops requiring few purchased inputs may also be an attractive proposition for rice-system farmers in appropriate ecozones. These species are of tropical and sub-tropical Asian origin. They cannot tolerate water-logging, but they can tolerate drought. Napier grass is already used in Asia as a cut-and-carry livestock feed. It has potential (Tucker and Johnson, 2001) as a biodegradable mouldable material for automobile and other applications. Cultivars of *Miscanthus* are, in trials in semi-temperate ecozones, N-responsive and highly productive of biomass. They emit little nitrous oxide and provide ecological-niche habitats for mammals and birds. They can be established by labour-generating planting of tissue-culture-derived vegetative materials.

Importantly, there already exist successful prototypes, expected to be operational by 2015, for medium-scale *electrical-power generators* that use these grasses (and possibly others, such as sweet sorghum) as their renewable bio-fuel. Such generators could be compatible with strategies - as in ADB 2000a, and possibly in the pro-poor objectives of the Japan Fund for Poverty Reduction - for innovative generation of renewable rural energy. Such energy generation could be perceived within an Agenda-21 / Kyoto-Protocol scenario - perhaps particularly for rice-growing countries that are not petroleum producers.

[It is perhaps pertinent to observe here that the European Union has a pioneering network of research and development for crops for industry and energy - in which Miscanthus and other tropical-origin grasses are featured. Arrangements might be made to avail of that network's expertise and experience - and perhaps of a World Bank "Learning and Innovation Loan" - to evaluate the potential of these (and of other) quick-growing grasses as prospective electricity-generating bio-fuels - and perhaps within a women-oriented pilot project in partnership with NGOs and academia. There are also coordinated bio-fuel-grass programmes in North America, and possibly in Japan.]

4.6 Socio-Economics, policies and wellbeing

Many of this document's paragraphs have relevance and implication for the socio-economics and for the wellbeing of rural households and for the several agricultural policies that affect rural communities. This present section correspondingly highlights, from among those preceding items, various economic, policy, and social features that impact strongly on those rural households and their livelihoods - and on their legitimate aspirations to improve those livelihoods.

Interventions through which FAO and partner agencies could assist member governments to improve the livelihood and wellbeing of rural rice-based communities would expect to be *integrative* - of technological, infrastructural, and socio-economic components - as urged by various stakeholders (UK/DFID 2000; FAO 2000g 2001a, IFAD 2001, World Bank 2001a, b), and as conceived within the FAO-facilitated Special Programme for Food Security.

Interventions would be guided also by the various and well-documented "codes of best practice" - such as the IRRI-IFAD-ICAR-IIRR (2000) *"Sourcebook of Best Practices and Strategies"* (for rainfed rice systems) and the *"Rice-Check Methodology"* (for irrigated and for favourably-rainfed rice systems). These codes variously and appropriately emphasize the needs for participatory appraisal, planning, and action - whether of research, development, extension, implementation, or evaluation. They emphasize also the need for maximal adoption of indigenous and locally-relevant knowledge, experience, and technology.

4.6.1 Micro-finance aspects

Among socio-economic concerns, those of reliable access to *micro-finance facilities,* and of *endowments* and associated services, are especially important to rural households. *Micro-credit* and *micro-savings* are important particularly for "smoothing" of income and consumption; important also - through their *insurance* aspect - for lessening household vulnerability to illness, emergencies, catastrophes, and income interruption (IFAD 2001, IFPRI 2001). Micro-finance serves also (ADB 2000a) to build the confidence to save, to borrow, and to invest - and is thereby important in the longer term, and in some circumstances, for family investment in human capital *via children's education.* However, IFAD (2001) advises that *poor* clients use micro-finance

services primarily as a source for several small, emergency loans, rather than for a single, large, investment loan.

Within the Asian rice-based food-and-livelihood support systems, and indeed within other farming systems, the availability of micro-finance is often a crucial pre-condition for the *adoption of new technologies*. Such micro-finance, whether from savings or credit, may sometimes be provided from within the family or extended family. With such finance, from whatever source, farmers on even the *smallest holdings* are not averse to new-technology adoption - as is quantified by the all-India analyses described in chapter 1.4.2. Micro-finance services are thus well recognized as a valuable support to smallholder agricultural production, and perhaps to the lessening of farm-family *hunger*.

However, IFAD (2001) strongly cautions that the extent to which micro-finance lessens long-term *poverty* is *uncertain*. It suggests that micro-finance is perhaps most effective in alleviating *short-term* transitory poverty, and more likely to be effective in lessening *long-term* poverty when used as an adjunct to other poverty-alleviating measures.

Relatedly, ADB (2000a Appendix 2) estimates that 95 percent of poor Asian families - rural and urban - are unable to access *institutional* financial services and credit. More generally, IFAD (2001, quoting Hulme 2000) states: "many micro-finance institutions virtually never work with the poorest . . . and many have high proportions of non-poor clients". This notwithstanding IFPRI's (2001) observation that poor people, and smallholder families, are willing and able to borrow at market rates. ADB (2000a 2001a) and IFAD (2001) similarly emphasize that procedures of subsidized credit are misguided, and that planned interventions should have sufficient profitability that they can effect full-costs recovery.

Singh and Houtman (2002) caution, however, that the poorest families need intensive training before they can access and benefit from the formal micro-finance system. The high costs of this training might appropriately be borne through donor assistance, rather than by the financial institutions. Similarly, ADB (2000a) notes that micro-finance understandably has higher transaction costs for unsecured small loans - though these costs can be lessened for loans to groups of persons. Correspondingly, Singh and Houtman (2002) note that because of their large numbers of small transactions, the micro-finance institutions need large-capacity data-management systems.

To poor rural people - and especially to the women and illiterate among them - the *"long-term borrowing privilege"* is a crucial endowment, particularly at times of emergencies. The ability of the *informal* credit sector to provide such long-term privilege, and to respond quickly and with minimal bureaucracy, is in part the reason that poor people may prefer the informal to the formal, project-constrained, shorter-term systems - notwithstanding that the latter may offer a wider range of options ("products"). Moreover, the informal systems do not require - and many formal systems do require - a regular attendance of clients at meetings; this feature is important for poor *migrant-worker* clients. Similarly, formal-system requirements for loan repayment through regular instalments can cause difficulty for poorer borrowers whose cash-flow may be highly irregular.

There is thus a recognized need (ADB 2000a 2001a, World Bank 2001a) to strengthen the capacity of such agencies as can provide micro-finance services that incorporate strongly the features that are required by the rural poor. Particularly, micro-finance components within short-term projects are more likely to provide long-term benefit if they operate through the existing micro-finance system rather than as a stand-alone finite-duration facility.

The informal sector, and also the formal sector through Grameen-Bank-type programmes, both recognize that for poor borrowers *social collateral* is a worthy and necessary substitute for the unavailable physical collateral. However, the informal localized rural-micro-credit sector is subject to high "risk covariance" in that a single event or situation (natural disaster, or crop failure) can result in a simultaneous repayment-default by many borrowers. The informal micro-credit suppliers therefore understandably practise judicious loan rationing. Borrowers correspondingly enhance their "credit worthiness" by availing of part, only, of their informal credit limit.

For those rural poor, including many landless poor, who have neither borrowing privilege nor credit worthiness, the formalized systems of *safety nets*, including food-for-work programmes - perhaps subsuming

some irrigation-maintenance work, as reported (IFAD 2001) for Bangladesh and Maharashtra, India - provide a vital means of survival (FAO 1998b).

In providing assistance and credit to these very poor persons, the need to identify the target clientele is well recognized (FAO 1998b; IFPRI 2001). IFPRI thus has a procedure - involving 300 indicators - to quantify the means available to households to fulfil their basic needs; and UNDP compiles an internationally applicable "human-development index". FAO (1998b) commends procedures whereby the target clientele has incentive to avail of pro-poor benefits of assistance and credit, but non-target persons have no incentive to pre-empt those benefits; procedures of "self-selection" of bene-ficiaries can be successful. FAO (1998b) cautions also that well-targeted programmes may be "de-railed" by powerful local politicians. ADB (2001a Appendix 4) similarly advises that reforms to rural-finance-market policies are more-often blocked by political obstacles than by economic forces. These dangers may increase when administrations are decentralized.

An IFPRI (2001) global database records the numbers, locations, and sizes of rural micro-finance institutions, including NGO-operated institutions. These institutions have (at 1997) a global clientele of 54 M (million) members - the great majority of them in Asia - and administer US$ 18 B of outstanding loans, and US$ 13 B of savings. Micro-finance is indeed (Singh and Houtman 2002) an emerging industry - an industry that is largely the creation of the non-governmental and private sectors. About one-half of the operational micro-finance institutions have fewer than 2 500 members, but one-in-twelve have more than 100 000 members. IFPRI (2001) reports that - for logistic reasons - the institutions in Bangladesh, and perhaps elsewhere, tend to have a lesser concentration of branches, in relation to numbers of poor persons, in remote impoverished regions as compared to more-developed rural regions.

[FAO, with various partners, assists member governments and projects through training, advice, and tools for micro-finance - as through the FAO-GTZ MicroBanking software and the Partnership Programme on Capacity Building in Rural Finance.]

4.6.2 Essential endowments: institutional, physical and human

Other *endowments* that are most needed by riceland families - and particularly by the poor and landless families - include legally-assigned land - no matter how small, equitable access to irrigation (where available) and to potable drinking water and sanitation, and to agricultural-extension services, functional institutions, infrastructures, and markets (IFAD 2001, Dixon *et al* 2001), and viable opportunities, including necessary entry permits and appropriate skills training, for rural enterprises. Transparent systems of justice - and their enforcement - are pre-requisite; as also is good governance (ADB 2001c, World Bank 2001a). Similarly, education, health care, supported by food-quality-monitoring facilities, and other social services are endowments that require strengthening in rural areas if populations and communities are to be retained against the forces of rural-urban migration. Such services will bring benefit also of increased capability and competence to perform successfully in food-production and in associated rural enterprises, including enterprises sub-contracted by urban manufacturers.

Functional *institutions* - national, province / state, district, sub-district, and village - are essential for pro-poor rural development. In some rice-growing countries and ecozones, there is need to *strengthen* those national and those devolved institutional capacities that assist government, civil society and community-based organizations, and producers' associations / co-operatives, to participate collectively in the formulation and implementation of rural-development policies and programmes. In some countries, such strengthening shall need to include actions to improve the mechanisms / procedures wherewith powers and responsibilities become legally devolved from the national ministries / departments, and to familiarize the national and the regional / local agencies with the content and implication of those mechanisms.

Institutional strengthening is expressly needed to enable the poor to secure and to retain usage / ownership entitlements to individual-household *land-based resources,* and to properties operated in common, and to facilitate smallholder-organization capacity to manage such common properties. There shall be an associated need for programmes and resources to facilitate, both nationally and locally, efficient procedures of land registration and administration. For some land systems, including some irrigated ricelands, such procedures shall require to accommodate the various types of tenure and of rights - whether private property of individuals or of groups, open-access, common-property, state property held in trusteeship, or other.

Fortunately, much of the required institutional strengthening can draw on substantial bodies of instructional materials and educational toolkits on aspects such as devolution mechanisms, co-operatives organization and operation, and capacity building for poverty alleviation and for small-business planning and development. Ongoing efforts in capacity building for small-business planning would expect to benefit from maximal synergy with technical specialists in primary production and in value-adding technology - whether for crops, livestock, fish, or forest products. Institutional strengthening can draw also on the effective procedures of "success-case replication".

[FAO (2000a) has the expertise and mandate to contribute, within multi-sector integrated programmes and through its Rural Development Division (Rome and Bangkok), to much of this urgently-needed rural development.]

Similarly, pro-active *skills and vocational training* shall be a highly worthwhile endowment investment - preparing current and future farmers and farm-family women for the transformed rice-system agriculture of 2010-20 and 2020-30 (IFAD 2001, Dixon *et al* 2001, FAO 1999c). Skills shall be needed in managing the new types of rice plant, and in managing the non-rice crops, including oil crops and feed crops and perhaps bio-fuel crops, that are grown in sequence or in association with that rice. Skills shall be needed also in modern techniques - of husbandry, reproduction, health, and hygiene - for poultry- and ruminant-livestock management. And skills especially in managing the complexities of the integrated farm system - including financial and value-adding and marketing aspects.

However, among *current rice-system farmers,* few have *formal education* beyond primary level, and many have not even completed primary schooling. They nonetheless have *indigenous knowledge* of agricultural practices and economics. For these current farmers, appropriate training might best be provided through agricultural extension programmes, perhaps adopting the FAO model of Farmers' Field Schools, emphasizing "training of trainers" and "lead farmers". Such procedures have had notable success in training women farmers in seed collection and management. Similarly, the Rice-Wheat Consortium (2000b) reports excellent results (in Bangladesh) for a well-prepared and personal-invitation *"whole-family training"* on practical aspects of wheat management within rice-wheat-system farming. This particular training methodology may expect to provide to farm-family enterprises the enthusiasm and dynamism and new knowledge of the young, together with the wisdom and experience of their elders.

But different strategies shall be needed for the *future farmers* - who are already receiving benefit, not available to their forebears, of substantially more formal education. Some of these future farmers may wish to become *specialists* in a particular crop or livestock commodity. For all of them, development of community-level information-technology (inter-net) extension services and adaptation of the Field-School model could avail of the increased literacy and numeracy and computer competence provided by their expanded education. Such development and adaptation should assist the riceland farmers, and the associated entrepreneurs and next-generation extensionists and adaptive researchers (ADB 2001b) to acquire the agricultural and the entrepreneurial expertise that will equip them to share in the increases in national wealth that shall derive from the general expansion of Asian economies.

For *today's* rice-system farming, many excellent *extension and training materials* remain little-used by their intended practitioners because they are available in English-language only. However, for almost all rice-growing ecozones there are now computer-software packages wherewith these English-language materials can with relatively little effort and cost be translated into the local language. A vigorous and selective *programme of translations,* and perhaps of co-publication, would constitute a very cost-effective training intervention by FAO and partners and sponsors.

[FAO is the custodian and publicist for WAICENT - the World Agricultural Information Centre.]

4.6.3 Gender aspects

Crucial for overall rural development - and for alleviation of rural hunger and poverty - is *rural-women's development.* Thus, IFPRI (2000a) analysis indicates that among five candidate determinants of child undernourishment, *women's status and education* explain far more (43%) of the undernourishment variance than do food availability (26%) or income per person or democracy or safe water. The mechanisms whereby women's status and education are postulated to lessen hunger and poverty are increases in standards of family care, in food management, and in woman-controlled family income. It is thus encouraging to publicize a

report from Bangladesh (IFAD 2001) describing an NGO-facilitated programme wherein rural women successfully control water-yielding assets and receive the proceeds of water sales to farmers.

For poverty, specifically, ADB (2000a Box 1) stresses that *"improving the political, legal, cultural, economic, and social status of women is pivotal to poverty eradication"*. Indeed, the poverty-alleviating success of the Grameen-Bank procedures has in part been mediated through the increase in the collective and individual self-respect and status of the female members. Nonetheless, in many rice ecozones, female heads of households, and female farm managers, still have lesser status and opportunities, and fewer legal rights (IFAD 2001 Box 3.8), than their male counterparts. Thus - and acknowledging the reality of rural-urban male migration - there is strong need to target support, including adult education, to those rural women who perforce operate as head both of the farm family and of the farm enterprise.

Addressing the overall developmental benefits of women's education, UK/DFID (2000) emphasizes that *"education of girls is probably the single most effective investment in development that any country can make."* Similarly, ADB (1998) stresses that *"investment in the education of girls brings long-lasting returns to society"*. The international (Year-2000) undertaking of the Dakar Educational Framework for Action is expressly helpful: "No countries seriously committed to *education for all* will be thwarted in their achievement of that goal by lack of resources" - with the understanding that resources shall extend to such essential costs as books, uniform, and transport. Significantly for *rural-poverty* alleviation, IFAD (2001) reports that incremental education to females gives larger increases to household income than does incremental education to males.

It is similarly noteworthy to recall the UN system target (and the Manila-Declaration target) to eliminate gender disparity in primary and secondary education by Year 2005. However, and notwithstanding the encouraging trend in net primary school female enrolment, UK/DFID (2000, citing UNICEF) and ADB (2000a) caution that the *statistical reality* of actual *non*-attendance, as distinct from non-enrolment, is that in South Asia 26 percent of male children, but 38 percent of female children, fail to attend primary school. IFAD (2001 Table 2.6 quoting UNESCO) reports that this South-Asia male/ female disparity in schooling and literacy is substantially higher in rural than in urban areas. Consequently, in South Asia, women's literacy rate is inferior to that of Sub-Saharan Africa. Rice-system technical assistance (to member governments) by FAO and partners must therefore be mindful of the vital need for women's education and development.

Fortunately, rice-system interventions do afford opportunities to educate, to train, and to empower rice-farm women. Indeed, women's economic contribution to Asian rice production is immense but generally unrecognized and unappreciated. Among those contributions, and in several rice-production systems, women have responsibility for specific and important components of the crop management and processing - perhaps undertaking four-fifths of the workload in transplanting and weeding and in harvest and post-harvest operations (IRRI-IFAD 2000). Notably, and in various parts of Asia's riceland, rural women have a specialist role in seed management and in livestock husbandry (FAO 1999c).

Thus, women-oriented skills training in these various activities - publicising the "best-practice" methodologies already validated through FAO and through other-agency projects - could constitute a highly cost-effective investment. Training would thus be especially appropriate in seed management, and in fodder production and in straw (livestock-feed) management - including the aspects of straw (feed) nutritional quality and the enhancement thereof through urea supplementation and bacterial inoculation (FAO 2001a). Training of women in general aspects of livestock management would similarly be a worthwhile investment (FAO 1999c). Correspondingly, seed-knowledgeable women have expertise and experience to contribute to farmer-participatory research and cultivar selection.

However, the provision of women-pertinent rice-system and rice-enterprise training shall need to be supplemented by a strengthening of the ongoing efforts that seek to develop *technologies and tools* that are appropriate to farm-family women and to their duties and time constraints. Such tools must also (IFAD 2001) be applicable to the production and processing of poor people's food staples.

Worrisomely, it is cautionary to note that poor rural women derive cash or share-crop income from rice transplanting. Pro-poor and pro-family programmes and policies for the ricelands shall thus need to be mindful of the labour-displacing adoption of direct seeding - compared to transplanting - of lowland rice.

Loss of this income could have serious consequence, since income that is earned by rural women is more likely to be invested in the education of female children.

It is noteworthy also that poor rural women's off-farm activities, such as fuel and fodder gathering, may be severely impeded during periods of drought. The involvement of farm-family women, and perhaps of their increasingly environment-conscious children, in *whole-family agricultural training* and in the implementation of SARM resource-management methodologies (as recommended in FAO 1999b) could thus be a very worthy investment. Integratively, training of adult rural women in the basics of *financial management* would expect to provide vital strengthening to farm-household economics and hence to family and community wellbeing.

For *farm-family nutrition*, interventions may usefully assist rice-system women to avail (perhaps with NGO and CBO partnerships) of the proven systems of maximization of benefits from *home gardens* and from the FAO programmes and publications on *making maximal nutritional use of available food* (FAO 1999a).

In rice-growing countries where the prevalence of *low (human) birth weight* is worrisomely high (Bangladesh, Cambodia, India, Myanmar, Nepal, Pakistan and Sri Lanka in that context), such *nutrition-oriented interventions* would provide effective augmentation to those ongoing programmes (national, UNICEF, WHO, others) that already are addressing low-birth-weight incidence. Better-developed infants - and hence better-developed children and adolescents - are likely when adult to be innovative and energetic as rice-system workers and managers, and correspondingly better able to contribute to the strengthening of rural enterprises, environments, and governance. FAO has the mandate and expertise - and indeed the obligation - to be a major participant in such integrated interventions.

Procedurally (and following ADB 1998 and other sponsoring agencies), it shall be expected that all interventions that aim to improve the wellbeing and status of rural women shall be integrated ("main-streamed" - and not "stand-alone") within all appropriate rural-development and rural-hunger-and-poverty-alleviation programmes.

4.6.4 Policy aspects

FAO similarly has the mandate and the expertise to assist member governments to devise and to target and to implement *policies* that can facilitate smallholder enterprise, rural livelihood, poverty alleviation and food security. This publication indicated the benefits that *smallholder* rice farms can make to the agricultural and to the national economies, and to food security. FAO might correspondingly assist governments and agencies to review their current agricultural and rural-development policies and if appropriate to modify them so as to maximize smallholder activity and output - noting IFAD's (2001) insistence that priority must be accorded to investment and to research/extension for poor-people's food staples.

Such assistance to national and to devolved government should expect to include components to strengthen the *institutional capacity* to define and to implement policies and procedures - for primary production, for value-adding enterprise, and for infrastructural supports. Prominence might be accorded to aspects of resource-use rights and tenure, of training, and of information provision, for all rural-livelihoods stakeholders. In training and information provision, priority stakeholders would be the farm families and the agricultural extensionists. For each of those groups, pro-active capacity strengthening would accommodate the differing needs and capabilities of the current generation and its successor generation.

To enhance food security and community-scale rural enterprise, policy might usefully initiate *tax-incentive* mechanisms, analogous to the forestry-investment incentive in industrialized countries, wherewith the private sector can be encouraged to invest in smallholder agriculture. Correspondingly, for the *remote ricelands*, particularly the upland and deepwater areas, policy can facilitate the public-sector provision of those rural infrastructures that shall attract private-sector employment-creating investment, and can further facilitate rural employment through justifiable environment-conserving incentives and appropriate food-for-work programmes.

The identification and subsequent repeal or amendment of *anti-rural and anti-agricultural and anti-smallholder* policies and fiscal regimes is especially important for the rural communities - and correspondingly important for the broader national interest. So also is the need to identify and to remove the impediments to the operation of existing policies, statutes, and regulations. The urgency for such actions is recognized in a recent draft for the World Bank's (2001a) rural development strategy, which places the

crafting of efficient and pro-poor policies as the first of its strategic priorities - and notably so for East Asia. Similarly, country-specific pricing policy for rice and for other poor-person staples may take account of the sources of marketable surpluses in determining the most-appropriate pro-poor food-pricing strategy.

Generally, there is for agriculture and for the rural economies a need to review and to revise inappropriate and environment-damage-provoking regimes of *subsidies and price supports:* in ADB-2001c and IFAD-2001 and World Bank-2001a terminology: the *"perverse and distortionary incentives"*.

Correspondingly, a strengthening of environment-enhancing policies, as of crop-nutritional procedures and livestock-excreta management and of crop / livestock / fish synergies, and of forest / water-shed management, would promote sustainable food security and increased rural incomes. Thus, acknowledging that pro-rural-poor strategies should be labour-absorbing and job-creating (ADB 2000a, IFAD 2001 and World Bank 2001a), there is high merit in SARM recommendations (FAO 1999b) that *taxes on labour should be repealed and replaced by taxes on natural resources.*

Similarly, well-founded policies on *common-property management* - perhaps adapting the procedures of the fishermen in Alanya, Turkey or in the Oxbow Lakes of Bangladesh - can protect natural resources and promote their sustainable utilization. ADB (2001a) similarly urges that policies - perhaps including taxation policies - should reflect the scarcity value of natural resources as inputs and sinks for anthropogenic activities.

[FAO has the expertise and mandate to advise and assist member countries in matters of agricultural-taxation policy and of common-property management, and to do so in consonance with holistic policies for rural-livelihoods improvement.]

Gender-related policies are recognized as being needed - and are being pursued by several member governments and civil societies - to address the issues that were featured in this document's immediately preceding section. Policies may need to recognize explicitly the economic inputs of farm-family women to rice-system production and food security and to farm-family and to rural-community nutrition and welfare. Legal embodiment of policies shall almost certainly be needed - and external assistance provided thereto - to assist rural women to attain equitable access to assets, entitlements, and production-facilitating and income-generating resources, and to education and to legal procedures.

For policy relating to *micro-finance*, the role of government, perhaps with donor and private-sector assistance, is to ensure a regulatory and registratory and supervisory system in which micro-finance institutions can flourish. There is complementary requirement for appropriate standardization and risk-assessment procedures that will prove attractive to commercial capital. However, IFAD (2001) counsels that "untrammelled financial markets cannot expect to lessen long-term poverty".

For the rice systems during the oncoming three decades, *water*-related policies shall be prominent. Policies relevant to a new century shall be needed to facilitate the modernization and maintenance of many of the older rice-irrigation systems. Such policies shall need to accommodate the concerns for accountability, system-management capability, and incentives, and for equitable treatment for upstream and downstream lands and for those dependent on groundwater and those on gravity-flow (surface) water. They may accommodate also the possibility of water-efficient "aerobic-rice" cultivars.

Importantly, and irrespective of whether such water-related policies shall be determined by central government or by decentralized government, it shall not be possible to ignore the legitimate demands of non-rice users of diverted water (ADB 2001c), nor to retain unjustifiable water subsidies (IFAD 2001). Thus, for irrigated-rice users of water, there shall be consequential requirement for policies that promote and enforce productive water use. Such policies are likely to be based on equitable, but contentious, systems of water rights and water obligations, and of water markets and water pricing - including a true pricing of electricity for tubewells, and must note from chapter 4.2.5 the technical difficulties of determining farm-level water costs.

[FAO is already assisting member governments to formulate policy options for their water sectors - including their irrigation components and the participatory management thereof.]

At the *global scale*, FAO, through its *Commodity and trade policy support to developing countries for trade negotiations*, and with partner agencies) is able and willing to assist member governments to adapt their national and international policies and strategies so as to achieve optimal benefits - including appropriate

"safety nets" and "Green-Box" benefits - from their membership of and from their prospective influence on the World Trade Organization.

5. Options for FAO-assisted interventions; outputs and monitoring

5.1 Interventions: methodology and procedure

The preceding sections suggest a multitude of options for interventions wherewith FAO, with partner agencies and intended beneficiaries, could assist national and decentralized governments to improve farm-family and rural-community livelihoods in Asia's rice-growing ecozones. Section 1.6.2 previewed how those options would be constituted as a "menu of packages" for consideration by the rice-system stakeholders - including member governments and prospective donors. It is indeed helpful that among those governments and donors there is strong political commitment to combat hunger, poverty and deprivation.

The interventions menu, presented in the following sections 5.2 - 5.4, features *technological* objectives, *socio-economic* objectives, and *institutional and infrastructural* objectives. It accommodates the needs to address the interactive triplet of food-security / human-nutrition, poverty alleviation and environmental sustainability; it is consistent with this document's vision and goals, and with the four components of the FAO-facilitated Special Programme for Food Security: *Identify constraints; Diversify enterprises; Intensify production; and Strengthen water management.* The menu is consistent also with the (draft) World-Bank (2001a) Rural Development Strategy and with FAO's (2001a) Global Farming Systems input to that Strategy. And consistent also with the global hunger/poverty-reduction strategy of Dixon *et al* (2001 Box 9.2): *Deploy science and technology; achieve sustainable and increased productivity of natural resources; enhance human capital and access to agricultural information;* and *refocus institutions and policies.*

Interventions would correspondingly seek to facilitate increased *investment* in rice-system smallholdings and in the families of the smallholders and of the rural landless, and particularly in rice-system women. Such investments would expect to achieve for those prospective beneficiaries - and for other rice-system dependants - the preservation and augmentation of income and employment opportunities and of assets and entitlements, and the strengthening of safety nets. Interventions and investments would expect to identify and to utilize community-specific comparative advantage and strengths - including any advantage obtainable through imports substitution. Among rice-dependent ecozones and communities, the technological, socio-economic and institutional interventions would collectively enhance the primary-production and added-value benefits from rice-system food crops (both poor-people's staples and higher-value foods), from feed and cash crops, from small-holding livestock, from fish (in some situations) and from agroforestry products (in upland ecozones); and in the longer term, perhaps from bio-fuel crops.

Interventions would be implemented holistically through a multi-stakeholder, multi-agency, multi-disciplinary coalition. As FAO (1998b) aptly states: "Partnerships of wide range are essential for food security". Indeed, for the alleviation both of food insecurity and of poverty, the holistic approach implies interventions that extend beyond the capacities of FAO. Thus, *integrated (decentralized)* rural development requires attention to education, particularly for girls and women, to health care, particularly maternity care, to infrastructures, including domestic and agricultural water, to transport for persons and goods, to rurally-sited storage and processing facilities and to savings / credit initiatives, perhaps featuring initiatives and incentives for remittances from the urban-migrated males.

The requisite partners, stakeholders and agencies would expect to include the beneficiary communities, locally-active NGOs, faith groups, *academia,* and private-sector companies and finance institutions, local and national agricultural-extension personnel, national and international agricultural research centres, various national ministries and component agencies, and several UN agencies. It is, however, necessary to caution that in some rice-growing countries there are constraints to inter-ministry collaborations and programmes, and that all UN agencies - including FAO - have finite mandates.

Nonetheless, we here specify the many UN programmes and agencies that, like FAO, have mandates and programmes that address issues of rural hunger, poverty and development. It is noteworthy that many of these

agencies, and similarly several national and multi-national agencies, have representation in Bangkok - as does FAO through its Regional Office for Asia and the Pacific. Those UN programmes and agencies, whether or not represented in Bangkok, include: *International Fund for Agricultural Development, United Nations Development Programme, United Nations Capital Development Fund, Economic and Social Commission for Asia and the Pacific, United Nations Development Fund for Women, United Nations Children's Fund, United Nations Environment Programme, World Food Programme, World Health Organization, United Nations Educational, Scientific, and Cultural Organization, United Nations Population Fund, International Labour Organization, and (through its Poverty Reduction and Growth Facility) the International Monetary Fund.*

From the "menu of packages" for prospective interventions, initial choices would be made by member governments, thereby ensuring congruence with their national policies, strategies and workplans: all interventions would thus be nationally-driven and not donor / facilitator-driven. Within countries and riceland communities, locally-specific choices would be made - to the extent that is possible and realistic - by the participant communities and farm families. However, as previewed earlier, the menu includes innovative interventions of which farm families could not be expected to be aware, and thus not likely to feature in village-level appraisals and "demand-driven" development portfolios.

The prospect to have collaborative action by several UN agencies permits particularly that interventions could be undertaken within the mandates of the UN Development Group, the UN Development Assistance Framework, and the UN Joint Consultation Group on Policy. Moreover, interventions could be accommodated within appropriate *thematic groups* of the multi-UN Agency Administrative Committee on Coordination and its Network on Rural Development and Food Security and its Sub-Committee on (Human) Nutrition. Such thematic groups operate by commodity, activity, and geography, and are expressly encouraged to seek new activities and synergies. Thematic groups relevant to rice community food security have active links to the World Bank Focus Programmes in Bangladesh, China, India, the Philippines and Viet Nam.

Targeting of prospective beneficiaries should - as with the selection of interventions - be accomplished in partnership with national agencies. The requirements are to target the vulnerable and the hungry/poor, and to do so through mechanisms, possibly of self-selection, that provide disincentives to the non-poor. Available mechanisms for identifying the poor and vulnerable, and among them the chronically poor and vulnerable, include the multi-component poverty-and-assets-quantification procedure of IFPRI (2001), and the emergent FAO-coordinated Food Insecurity and Vulnerability Information and Mapping System (FIVIMS). Agronomic targeting, important for national food security and for local poverty alleviation, can be achieved through the procedures of crop and livestock yield-gap analyses, supplemented by considerations of the available markets and infrastructures. The broad-scale indications (Dixon *et al* 2001) of candidate poverty-escape mechanisms - for East Asia and for South Asia and for their rice-rice-based and rice-wheat-based systems - can usefully complement the foregoing targeting mechanisms.

Operationally, and as previewed earlier, the interventions to which FAO would expect to make the major contribution, and which are listed in sections 5.2 to 5.4, shall expect to be implemented through a *twin-twin-track* strategy. In this strategy, the first twin pair would have one "track" for the non-irrigated ricelands, with the second "track" for the irrigated lands. In the second twin pair, one track would accommodate near-term interventions (2002 - 2006), and the second the medium term (2002 - 2012).

Within the first pairing, interventions in the *non-irrigated* (less-favoured) lands would expect to increase productivity, employment, and income, and hence help lessen rural hunger and poverty. These less-favoured lands comprise the *rainfed-lowland* (including *deepwater*) rice systems and the upland systems; in the latter there are many very poor families who depend for part of their subsistence on *upland rice*. Correspondingly, interventions in the irrigated lands that accommodate the *intensive rice-rice-based* and *rice-wheat-based* systems would help increase national food production, thereby enhancing food supply and security to rural and urban consumers, while increasing the income of the smallholder families. This twin-track strategy would thus expect to be fully compatible with the existing directives in the participant countries' medium-term agricultural-development plans.

Also in congruence with national plans, *emphasis* would be accorded to the non-irrigated ricelands. Such emphasis would be consistent also with the international-aid pro-poor and pro-hungry priorities as formulated in various high-level forums – e.g. the Doha and the Monterrey summits, and the June 2002 World Food Summit – and consistent also with the economic and social justifications presented in this document. For these

non-irrigated lands, investments can be considered to comprise a payment of part of the costs of lessening rural poverty and of conserving natural resources.

The second twin-track pairing acknowledges that many useful interventions can be implemented in the *near term* using available and developing technologies and procedures - particularly in the irrigated and more-favourably-rainfed areas. However, other interventions shall require a *longer timeframe* - as in the deeper-water and upland ecozones, where there is likely to be need for technological and social adaptations and evaluations. In all ecozones, longer timeframes shall be needed for aspects of policy redirection. New-technology interventions, as for bio-fuel-crop evaluation and livestock-management innovations, shall also require longer timeframes. Moreover, interventions - at both time scales - shall indeed involve technological, socio-economic, and institutional and training activities, variously addressing aspects of primary-production, added-value, and supports and services - whether for crops, livestock, fish, or agroforestry products.

For both irrigated and non-irrigated systems, the nature of the interventions would be the demonstration, adaptation, and facilitation of adoption for proven and documented *best-practice* procedures and technologies. There would be a complementary programme of *success-case replication* - variously accommodating the pertinent assets and strengths of the individual participant communities.

Rice-growing countries that might wish to be supported to journey along the irrigated "track" or on the non-irrigated "track" - or on both - may tentatively be identified using the current statistics for poverty and for intensity of hunger. For the irrigated "track", eight countries devote appreciable fractions of their riceland to intensive rice-rice or/and to intensive rice-wheat systems. Those eight are Bangladesh, China, India, Indonesia, Pakistan, Philippines, Sri Lanka and Viet Nam. A ninth country - DPRKorea - is by climate unsuited to rice-rice cropping. However, DPRKorea is evaluating the intensive winterwheat-rice and potato-rice sequences, and may wish to consider whether some of the methodology and technologies here proposed might be relevant to its wheat-rice and potato-rice sequences.

For the non-irrigated "track", eight low-income and food-deficit rice-growing countries have at least 10 percent (and often much more) of their riceland in one or more of the categories of rainfed lowland, rainfed floodprone / deep-water, and rainfed upland. They comprise Bangladesh, Cambodia, India, DPRKorea, Laos, Nepal, Philippines and Viet Nam. Those eight and possibly Myanmar, Sri Lanka and Thailand, may wish to consider whether any items from the "menu of packages" would be appropriate to their lowland-rice smallholdings farms - and especially to the women-managed smallholdings.

The menu of best-practice packages is in sections 5.2 to 5.4 presented in summary format. That format will enable various stakeholders to make an initial appraisal and prospective commitment to specific menu items and to the strategy here proposed. As highlighted in several preceding paragraphs, FAO is able and willing to assist member governments in making such appraisal, and in ensuring congruence with their national agricultural/ rural-development plans. FAO would also assist in attempts to quantify the added value that derives from multi-disciplinary multi-stakeholder interventions. Subsequently, FAO will prepare a portfolio of semi-detailed proposals for those menu items that are favoured by stakeholders. Section 5.5 summarizes the indicative outputs expected from the proposed interventions.

Some items within the menu of packages shall be suitable for formulation as pilot projects incorporating best practices and success cases. As such, they might be particularly appropriate for inclusion in programmes to strengthen devolution of administrative/technological functions - as was recommended by the United Nations Capital Development Fund. Other items would be candidates for sponsorship through FAO as sub-regional or as single-country technical co-operation programmes.

The urgency and the political will for pro-poor food-security action - as shall be emphasized in the June-2002 World Food Summit - is immense. Action is needed immediately to combat current hunger - particularly among the very young. Additionally, family-oriented and policy-directed interventions must help achieve the vital socio-economic and socio-political goals of providing to the younger generation of poor and hungry persons - both males and females - a realistic expectation that their lifestyles and livelihoods shall be more agreeable than those of their parents. Such interventions must commence now if the younger generation's aspirations for year 2030 are to be met.

5.2 Interventions: technological

Options for *technological* interventions, and for which FAO could act as a facilitator of adaptations and adoptions, are here presented in relation to primary productivity, to value-adding processing, and to sustainable resource management. They are formulated within the context of food security and poverty alleviation, and of a holistic and participatory implementation in which key non-technological aspects - as of the fuller involvement of women in rural-livelihoods development - would be "main-streamed".

Technological interventions would comprise demonstrations and supports to the smallholding adoption of proven best practices and success-case experiences, with some supplementary applied studies. They would target the poor-people staples - including rice - but also feed crops and some higher-value non-rice crops. They would target also the rice-smallholding livestock, fish, and agroforestry products, and would utilize the beneficial synergies and interactions among the several farming-system components. Interventions shall thus be location-specific, and would correspondingly expect to be guided by participatory appraisals, with and for the beneficiary communities, of both the technical/agronomic and the socio-economic / cultural constraints. Those appraisals, similarly, would be mindful of the prospective, location-specific, poverty-escape mechanisms, and of the implications for intensification and diversification of the farming-system components.

Within the *twin-twin-track* strategy, the interventions here proposed are segregated according to their applicability to non-irrigated, to irrigated, or to all rice-based systems. They are code-referenced for ease of follow-up and administration, and are categorized as to whether appropriate for near-term or for medium-term support and implementation. They are described in summary.

The identifier alpha-numeric codes are constituted and sequenced as follows:

- T: Technological intervention; E: Economic or social intervention; I: Institutional or infrastructural.
- B: Both non-irrigated and irrigated rice systems; N: Non-irrigated systems; I: Irrigated systems.
- C: Crops; L: Livestock; F: Fish; A: Agroforestry; P: Policy; V: Value-adding; T: Training, information and capacity strengthening; S: Sustainable natural resource use.
- 2: Identifier number within the preceding codes.

5.2.1 All rice-based systems: non-irrigated or irrigated

The following technological interventions may be applicable to the non-irrigated rice systems *(rainfed-lowland, deepwater, or upland)* and also to the *irrigated* systems.

T.B.C.1: Use of existing GIS and FIVIMS databases and analytical agro-ecological procedures and of existing constraints analyses and community-assets appraisals to explore *location-specific cost-effective technological options* for rice/non-rice - including agroforestry - and for rice/rice/non-rice and rice/wheat/non-rice sequences, relays, mixtures, and inter-croppings that are compatible with feasible farming systems and with accessible inputs and markets and infrastructures and for which the requisite cultivars can be acquired nationally or through FAO international assistance.

(Near-term activity; linked to T.N.C.2, I.N.S.2, I.I.P.1)

T.B.C.2: Strengthen within-community technologies and procedures to acquire and to manage and increase supplies and *quality of seeds* for preferred cultivars - traditional, modern, vitamin / micro-nutrient-enriched, and hybrid - for rice and non-rice crops (including feed crops).

(Medium-term activity; linked to E.B.T.1, I.B.P.3)

T.B.C.3: Facilitate and support, for rice and non-rice crops, operator-safe and effective *control of weeds, pathogens, pest-insects, molluscs* (irrigated systems), and (to the extent practicable) rats and birds through training-and-demonstration programmes and taxation and regulatory regimes to improve labelling and to lessen excessive use and mistimed applications of pesticides and to incorporate biological, biotechnological, and threshold-level controls where appropriate.

(Near-term activity; linked to I.B.P.2)

T.B.L.1: Assistance to enable smallholders to benefit maximally from the expected increase in demand for livestock products by availing of small-farm *crop-livestock synergies*, including opportunities to produce livestock feeds. Interventions confined to areas where smallholders may expect to be price-

competitive against large-scale enterprises, and where livestock-yield-gap analyses suggest potential for much-increased productivity. Assistance through facilitated access to improved breeds / hybrids of poultry and of ruminants, and to quality stock for such breeds / hybrids. Assistance also through guidance on technologies to supply and augment feeds from own-farm crop products and by-products, and for crop-nutrition strengthening using livestock manures and composts. Location-specific livestock options may include native chicken, and native and hybrid duck; and for irrigated and favourably-rainfed areas: cattle for fattening and for dairy, pigs, and possibly improved buffalo for meat (South-East Asia); and for upland and less-favourably-rainfed areas: sheep and goats. Guidance and support correspondingly in livestock housing (including communal housing), feeding, reproductive and health management, and in micro-finance and post-production and marketing activities.

(Near-term activity; linked to T.B.V.1, E.B.V.2, E.B.T.1)

T.B.V.1: For smallholder *livestock:* assistance to provide or strengthen post-production *added value* through introduction in villages and/or townships of proven appropriate-technology procedures for slaughter and dressing for poultry and ruminants, and through training / facilities for meat inspection for food-safety-conscious markets and supermarkets. Guidance / assistance also on technology for incorporation of livestock products into low-cost protein products for rural communities and their school-lunch services. For smallholder dairy enterprises, assistance to utilize new milk-preservation technologies using lactoperoxidase and combined pasteurization / packaging. Guidance also on technologies to enhance the added value achievable for hides, horn, fibre and feathers.

(Near-term activity; linked to T.B.L.1 and E.B.V.2)

T.B.V.2: For smallholders and communities, technological and market-research support and guidance for a set of options for value-adding processing of *rice-system food products and by-products* into noodles, breakfast cereals, sauces, soups, beverages, desserts and baby foods. Support also to community-scale production of *brown rice* and of *rice-bran* derivatives for health-conscious consumers, and of livestock-feed supplements through micro-biological processing of *rice straw*. Guidance and assistance also - and particularly for farm-family women - on known procedures to lessen post-harvest losses during processing and storage.

(Near-term activity; linked to E.B.V.1 and E.B.T.1)

T.B.S.1: Agronomic and socio-economic appraisals / investigations - perhaps in partnership with donor-country and NGO and local-academia specialists - of the potential for renewable-energy *bio-fuel* crops to be grown post-rice in irrigated and in non-irrigated ecozones. Agronomic investigations, perhaps targeting the tropical and sub-tropical *Miscanthus* and *Pennisetum purpureum*, to identify ecozone-specific cultivars and management practices, and to estimate prospective annual production and energy content. Technical studies to determine the suitability and annual bio-fuel requirement of existing prototype medium-scale electrical-power generators, and of their congruence with national and regional-growth-triangle energy strategies.

(Medium-term activity; linked to E.B.S.1 and I.N.S.1)

T.B.S.2: Facilitate a rice-system crop and livestock management that assists the global commitment to *lessen agricultural-nitrogen flows* to the aquatic and atmospheric environments, and that thereby increases rice-production efficiency and net income, and improves rice-soil "health". Technical guidance and supports to the understanding and adoption of environment-friendly decision-support systems and tools, including the "LEAD Toolbox" for livestock-excreta management, and the site-specific-nutrient-management and nutrient-exclusion-plot procedures and the leaf-colour-card tool for achieving balanced and efficient rice-crop fertilization. Efforts also to optimize the utilization and effectiveness of the rice-systems' soil-and-plant-analysis laboratories, and particularly their P-and-K-advisory programmes.

Initiate applied studies, which use procedures already validated by FAO, to identify - and subsequently to increase seed-availability for - farmer-acceptable *N-efficient rice cultivars*. Quantify for those cultivars the agronomic and economic efficiencies of combinations of manufactured fertilizers and livestock manures when used in conjunction with appropriate rice-plant-population density, seed quality, and pest and water management. Supplementary studies to use for fertilizer-

regulatory purposes a rigorous, distributor-acceptable methodology to evaluate simultaneously up to twenty proprietary fertilizer blends and compounds, growth-promoters, soil conditioners and micro-nutrient cocktails. [These various studies might appropriately be undertaken by national agencies mandated to operate "at the interface between extension and research".]

(Medium-term activity; linked to T.I.C.2, I.B.P.2, I.B.S.1)

5.2.2 Non-irrigated rice-based systems

This section groups those technological interventions that are applicable to the non-irrigated rice systems: *rainfed-lowland, deepwater and upland*. For the more-favourably-rainfed lowlands and for the deeper-water systems there are newly proven technologies and procedures that can be commended for demonstration to and evaluation by farm families. For the upland systems, there are prospective income-generating initiatives wherewith to supplement the resource-conserving procedures of SARM and of ILMT.

T.N.C.1: For favourably-rainfed *lowland rice*, demonstrations and supports to programmes of integrated rice-crop management based on the *rice-check* methodology with its *farmer-group* collective procedure of observe, measure, record, interpret, act, and with its agronomic emphasis on appropriate land preparation, sowing date, rice cultivar, plant population (whether transplanted or direct-seeded), pest control, water management, and leaf-N-guided nitrogen management, and with its accommodation of responsible target yield and farm-family risk strategy. Supplemental options to supply / evaluate candidate rice cultivars - including hybrids, new-plant-type, and vitamin-enhanced; and opportunity to sponsor and undertake collaborative breeder/ farmer rice-cultivar development to increase yield potential in high-price traditional deepwater-rice cultivars. Options also to evaluate improved intermediate-technology tools - including treadle- or diesel-powered water pumps, cono-weeder, serrated sickle, and seedling-nursery protection against virus vectors.

(Medium-term activity; linked to T.I.C.1, T.I.C.2, I.N.S.1, I.N.S.2)

T.N.C.2:For medium (0.3- 1.0 m) *deeper-water-rice* and for *favourably-rainfed-rice* regimes, demonstrations and supports to evaluate / adapt *best-practice* and *success-case* experiences for cultivars and management for *monsoon-season* rice and for high-yielding *post-monsoon* (cool-season) rice. Corresponding evaluations for success-case *pre-monsoon* and *post-monsoon* cropping-system options: sequences, inter-crops, mixtures, relays, and ratoons, and their candidate rice cultivars (including rainfed new plant-type) and intermediate-technology tools. Supplemental options to supply /evaluate candidate *non-rice* cultivars - including maize, oil-seeds, pulses, bio-fuel crops, and niche-specific high-value herbs, spices, colorants and pharmacia.

(Medium-term activity; linked to E.B.T.I, E.B.T.3, I.B.S.1, I.N.S.1)

T.N.A.1: For *upland-rice* agroforestry systems, provide supports, guidance, and assistance for income-generating initiatives wherewith to supplement the resource-conserving procedures of SARM and ILMT. Candidate initiatives include diesel-powered pumping of pond water to higher-elevation fields, within-farm interceptor plots to retain rainfall-runoff water, intermediate-technology tools, and niche-specific options for high-value crops - notably medicinal crops, and herbs, spices, and colorants. Options also to evaluate candidate upland-rice cultivars (including "aerobic-rice" cultivars) and to disseminate seeds thereof, and to sponsor and undertake collaborative breeder / farmer rice-cultivar selection and development. Initiatives also - with supportive Agenda-21 incentives - to assess and to grow carbon-sequestering crops and bio-fuel crops, and to maintain biodiversity-conserving crops, livestock, and habitats.

(Medium-term activity; linked to T.B.C.1, T.B.S.1, E.B.V.1, E.B.S.1, I.N.S.1, I.N.S.2)

5.2.3 Irrigated rice-based systems

This section groups those technological interventions that are applicable primarily to irrigated rice systems. For these irrigated systems, there are several newly-proven and emerging technologies. Enhanced dissemination of these technologies can be expected to impact quickly and favourably on rural food security and poverty reduction.

T.I.C.1: Support and guidance to *area-specific* agronomic assessment of *irrigated-rice yield gaps* and their components, assessed for currently-used cultivars, and for hybrid and new-plant-type cultivars, and for each rice crop within rice-rice and rice-rice-rice sequences. Corresponding determination of *realistically attainable* smallholder yields, and hence of responsible target yields within representative smallholder-household strategies to accommodate socio-economic and climate / pest risks. [These findings shall help target interventions, and shall be pertinent also to favourably-rainfed lowland rice.]

(Near-term activity; linked to T.B.C.1, T.I.C.2, I.B.P.4)

T.I.C.2: For irrigated systems, and for each rice crop within multi-rice sequences, and in relation to the locally-responsible target yield: demonstrations and supports to programmes of integrated rice-crop management using the *rice-check* methodology with its *farmer-group* collective procedure of observe, measure, record, interpret, act, and with its agronomic emphasis on appropriate land preparation, sowing date, rice cultivar, plant population (whether transplanted or direct-seeded), pest control, water management, and leaf-N-guided nitrogen management within a regime of site-specific balanced nutrition. Such regime to provide or replenish the nutrient off-takes, sustain "soil health" and minimize nutrients wastage.

Supplemental opportunity for farm-field determination of indigenous nutrient supplies capacity and hence for information-guided nutrients applications. Options also to demonstrate / evaluate water-saving procedures of post-dry-season shallow tillage and of non-continuous soil submergence. Opportunity to supply / evaluate candidate rice cultivars - including hybrids, new-plant-type, and vitamin-enhanced; and to evaluate improved intermediate-technology tools - water pump, cono-weeder, serrated sickle, and seedling-nursery protection against virus vectors.

(Near-term activity; linked to T.I.C.1, T.N.C.1, I.B.P.2, I.I.S.1)

T.I.F.1: Demonstrations and support for rice-fish systems that incorporate indigenous and introduced finfish, shrimp and crab: featuring management of the stocking, spawn and fingerling supply, supplementary feeding, health and hygiene, and fish-refuge and harvest and post-harvest procedures.

(Near-term activity; linked to E.B.V.2, E.B.T.1, I.B.T.2, I.B.S.1)

T.I.S.1: Demonstrations and support for paired-row irrigated-rice-geometry systems that facilitate rice-phase management and that permit prompt, rice-stubble-free minimal-tillage establishment and fertilization for post-rice coarse grains, oil seeds, field vegetables and pulses. For constrained soils, guidance and support to procedures (through Agenda-21) of carbon sequestration and bio-fuel production, and for saline soils, additionally, to procedures of conjunctive use of brackish and sweet waters.

(Near-term activity; linked to T.B.C.1, T.N.C.2, T.I.C.2, I.I.S.1)

5.3 Interventions: economic, social and wellbeing

This section proposes interventions to help improve the income-generating opportunities and the general wellbeing of rice-system dwellers, including the rural landless. The interventions thus seek to strengthen the processing and marketing of rice-system products, to strengthen rice communities' access to information, training, and adult education, and to enable rice-farm families to profit from their endeavours to improve the local, regional and global environments. On-farm and off-farm activities are proposed, variously in production and in processing, and also in agriculture-support services. Some activities extend beyond FAO's mandate and expertise: it shall thereby be necessary to forge partnerships with those agencies and stakeholders that can complement FAO's expertise and experience.

E.B.V.1: Community-specific guidance and support to identify market opportunities and price-competitive processing, packaging, distribution, and sales procedures for *rice products and by-products* - including high-value (and vitamin / micro-nutrient-enriched) health foods and convenience foods, and foods that incorporate ingredients from other rice-system crops, livestock and fish. Corresponding support to rice-farm communities to produce and market high-value low-bulk non-perishable products from *non-rice* crops - notably medicinals, spices, herbs and colorants. Support also to community-based *service enterprises* - as of small-scale rural transport, or of price-competitive repair, hire, or contractual supply/operation of rural equipment. For each enterprise, whether

production or service, assistance in business management and in meeting start-up and tooling costs, and in complying with legal and administrative requirements.

(Near-term activity; linked to T.B.V.2, E.B.V.2, I.B.P.1)

E.B.V.2: For rice households tending *livestock:* Assistance and support to producer groups and co-operatives to identify market opportunities and price-competitive processing, packaging, distribution, and sales procedures for meat, eggs, and dairy products, and for hide, horn and feather products. Support - where cost-effective - for the construction in villages and/or townships of appropriate-technology facilities for slaughter and dressing for poultry and ruminants, and for ensuring appropriate hygiene and food standards for food-safety-conscious markets and supermarkets. Assistance to assess feasibility, and to provide facilities, for using slaughterhouse blood meal as a low-cost poultry-feed ingredient. For rice-system dairy enterprises, assistance to initiate and to operate milk-preservation technologies using lactoperoxidase and combined pasteurization/packaging.

For ricefield *finfish, shellfish and eels:* assistance, including tools and facilities, to adapt and adopt proven technologies to produce, package, and market high-protein long-shelf-life products.

(Medium-term activity; linked to T.B.V.1, T.B.L.1, T.I.F.1, E.B.V.1, I.B.P.1)

E.B.S.1: Legal, technical, economic and marketing assistance to examine feasibility and cost-effectiveness - within the Agenda-21/Kyoto-Protocol financial supports and provisions for sustainable land utilization and within national power-generation strategies - of riceland employment-generating programmes of carbon sequestration, permanent land set-aside, and electricity generation from bio-fuel grasses and/or rice hulls.

Legal and administrative assistance to determine eligibility and suitability within national *pro-poor food-for-work* programmes of maintenance/restoration of sloping lands (ILMT and SARM) and of irrigation structures.

(Near-term activity; linked to T.B.S.1, I.B.P.2, I.B.S.1, I.I.P.1)

E.B.T.1: Strengthening of course materials and of skilled extensionists - female and male - to facilitate technical training and adult education for rice-smallholder families. Adapting where appropriate *whole-family-training* procedures to strengthen female members' technical knowledge and to access those members' agronomic and socio-economic expertise, and to engage the interest, enthusiasm, and modern knowledge of the near-adult children. Adapt and adopt existing training modules (including NGO-prepared modules) of *best practices, success cases and decision-support systems* for rice and non-rice crops, livestock, and ricefield fish, and for sustainable resource and common-properties management, and for value-adding and post-harvest technologies and enterprise management. Modules also that feature the available and prospective *hand-tools* that conserve employment but lessen drudgery: for pre-harvest and post-harvest tasks, for community-based service enterprises, and especially tools designed for women's use.

Forward planning of *farmers' field school curricula* for the transformed rice-system agriculture of 2010-30: featuring skills in managing new types of rice plant and of oil crops, feed crops and bio-fuel crops; skills in modern techniques of poultry- and ruminant-livestock management; and in managing the complexities of the integrated farm system, including financial and value-adding and marketing aspects.

Development of skills - technical, administrative, financial, and within existing seed-regulatory regimes - for rural *women* to expand and direct community-based *seed-management enterprises.*

(Near-term activity; linked to T.B.C.2, T.B.S.2, E.B.T.2, I.B.T.1, I.B.T.2)

E.B.T.2: Rice-community adult education - within *multi-agency curricula* addressing diverse rural topics - featuring aspects of *financial management* both of enterprises and *of households,* of nutrition, health, hygiene, and sanitation, and of the formation and operation of groups, associations and co-operatives.

Women-specific sessions to emphasize aspects of maternity care and of mother-and-child micro-nutrition so as to enhance nutritional use of available food and lessen the incidence of low-body-mass females, and to describe and encourage home-garden contributions to family nutrition.

Guidance also on incorporation of livestock products into low-cost high-protein foods for rural communities and their school-lunch services.

(Medium-term activity; linked to T.B.V.1, E.B.T.1, I.B.P.3, I.B.T.2)

E.B.T.3: Multi-agency support for rural *information* and knowledge sharing: to and from farm families, to and from extensionists and researchers and NGOs, to and from micro-finance and agricultural-inputs suppliers, and to and from non-agricultural rural entities. Utilizing *multi-media* channels: farmers' field schools, whole-family seminars, workshops, monitoring tours, brochures, reports, and television/radio; provision as appropriate of internet/telephone facilities for market-information access.

Use of low-cost soft-wares for *translation* and for *co-publication* in national languages of high-quality training/extension/best-practice materials and manuals - particularly for risk-prone rainfed-rice systems - that are currently available in English-language only.

(Medium-term activity; linked to T.N.C.2, T.I.C.2, E.B.T.1, E.B.T.2, I.B.P.1)

5.4 Interventions: institutions, policies and infrastructures

The following interventions are proposed to help strengthen national rural-development *institutions* - centralized and devolved, and to assist the upgrading of rural *infrastructure*, and to support initiatives to formulate and to implement pro-rural, pro-smallholder, pro-employment, and urban-migration-countering *policies*. All interventions shall require to be consistent with and supportive of the nationally-defined rural-development strategies. They must be consistent also with the particular assets and strengths of the intended beneficiary communities. As with some interventions suggested in preceding sections, so for the interventions here listed, and particularly among interventions for infrastructures that support social services, several extend beyond FAO's mandate and expertise. Correspondingly, for the rural-areas social services for education, health, and domestic water and sanitation, there is crucial need to strengthen not only the infrastructures, but also the scope and quality of the services. There is thus compelling need for multi-agency multi-stakeholder initiatives.

I.B.P.1: Assistance to develop a national policy that strengthens *rural infrastructures* and *transport / communications connections* and hence enables rural areas to attract employment-generating enterprises to cost-competitive production environments. Complementary policies - perhaps of medium-term tax incentives - to supplement that attractiveness to individual, urban-based, established companies.

Within that strengthened pro-rural national policy, support to *construct or refurbish* rural market halls and storage and food-processing and packaging facilities, buildings and start-up premises for value-adding enterprises and micro-finance services, and to *provide or upgrade* communications, economic links, and transport for persons and goods to identified urban and peri-urban markets.

(Medium-term activity; linked to E.B.V.1, E.B.V.2, I.B.P.2, I.I.P.1)

I.B.P.2: Policy assistance correspondingly to halt and reverse the downward trend in *national investments* in agriculture and rural development - notably in agricultural extension and adaptive research, and to encourage, through taxation incentives, private-sector investment in smallholder agriculture. Assistance also to identify and to repeal anti-smallholder and agri-agriculture policies, and to identify and remove impediments to the operation of existing policies, statutes, and regulations, and to initiate pro-rural and pro-smallholder policies that reward sustainable natural-resource management. Assistance, correspondingly, to strengthen the *rights* of smallholders and of governments in aspects of intellectual property and of indigenous germplasm.

Legal, regulatory and policy assistance to identify and phase out *anti-rural* and *anti-smallholder bias* in national regimes of taxation and fiscal policy; and to identify and phase out *perverse subsidies* that encourage and reward environmental degradation and resource misuse: particularly those for fertilizer, pesticides, livestock-feed concentrates, water, tubewells, electricity and credit. Assistance to ensure that *taxes on labour* are repealed and replaced by taxes on natural resources.

(Near-term activity; linked to T.B.S.2, E.B.V.1, E.B.V.2, E.B.S.1, I.N.S.1, I.I.S.1)

I.B.P.3: Policy and legal assistance to review and to strengthen national policy to enable rural families - and especially woman-headed families - to acquire and to retain legal access to social and financial services and to agricultural-extension services, and to the assets and entitlements of land and land markets, water, common properties and rural employment.

(Medium-term activity; linked to E.B.V.1, E.B.V.2, E.B.T.2, I.I.S.1)

I.B.P.4: Analytic assistance to generate *policy-guiding data and interpretations* that impact national pro-poor food-pricing strategy and rural food-security trends and forecasts. Determining, for smallholdings of various sizes and for landless share-croppers, the balance of own-farm production and consumption for staples and other food crops. Quantification of national and sub-national trends, using 6-year rather than 10-year time segments, and for comparison against human-population and food-demand growth-rate forecasts, in *yield per field day* for key crops, and in annual production for key crops and livestock, and in the all-agriculture- and in the food-production indices. Analyses also, using non-linear models, for trends in yield gaps for key staples.

(Near-term activity; linked to T.B.C.1, T.N.C.1, T.I.C.1)

I.B.T.1: Guidance and assistance to national and devolved governments to *strengthen institutions and develop human capacity* to support the formation and operation of *rural producer groups, associations and co-operatives,* and to assist those groups and associations to participate with civil-society and community-based and non-government organizations in formulating and implementing rural-development policies and programmes. Assistance, where needed, to improve the mechanisms wherewith powers become legally devolved from the national ministries, and to familiarize national and local agencies with the content and implication of those mechanisms. Within an overall strengthening of national and devolved *agricultural-extension and adaptive-research services,* strengthening of institutional capacity to assist small-business-development agencies, and to lessen administrative/legal constraints to co-operatives formation and to rural off-farm employment - including landless-person employment.

(Medium-term activity; linked to E.B.V.1, E.B.V.2, I.B.P.1, I.B.P.2, I.B.P.3, I.I.S.1)

I.B.T.2: Support to strengthen national capacity to extend the scope and efficiency of *micro-finance services* for rice-growing communities. Demand for such services is expected increase, as value-adding enterprises increase in number and size, and as expansion of rice-system livestock generates requirements for medium-term credit to purchase animals and feeds and to construct housing. Assistance, where needed, in aspects of regulation and standardization, and in establishing procedures for identifying the very poor families that most need financial and "safety-net" services, and for providing to those very poor clients the intensive training that shall enable them to understand and to utilize financial services. Advice and technical assistance on computer software and database hardware and operation for rural micro-finance networks.

(Near-term activity; linked to T.B.L.1, T.B.V.1, T.B.V.2)

I.B.T.3: For agricultural *trade within countries,* support to institutional capacity in strengthening and regulating fair-trading practices. For *international trade,* training and capacity development for individual countries and for country groupings to enhance capabilities to exert influence in the congresses and committees of the *World Trade Organization,* and thereby optimize their benefits of membership. Guidance particularly on procedures of the General System of Preferences, of the Committees on Provisions of Technical Barriers and Trade and on Provisions on Application of Sanitary and Phytosanitary Measures, and on effective utilization of the Advisory Centre on WTO Law; assistance also to adapt national policies and strategies so as to enhance access to WTO "Safety-Net" and "Green-Box" benefits. Support to establish and operate developing-country groups and growth triangles that can enhance bargaining power for international purchase or sale of agricultural commodities and products.

(Medium-term activity; linked to T.N.A.1, E.B.V.1, E.B.V.2, I.I.S.1)

I.B.S.1: Enhanced *sustainability* of natural resources and of communal man-made rural infrastructures, through "safety-net" programmes, institutions, training and policies that enable socially and

environmentally desirable construction and maintenance to be undertaken through *food-for-work* by the self-selected very poor - particularly in remote upland and deepwater areas. Qualifying food-for-work activities could include own-farm SARM and ILMT constructions/ plantings, large-area pest-control campaigns, on-farm water-conservation measures, irrigation-system maintenance, and repair / maintenance of market halls, fish-landing jetties, and farm-access roads and bridges.

(Medium-term activity; linked to T.N.A.1, E.B.S.1, E.B.T.1, I.I.S.1)

I.N.S.1: For non-irrigated ricelands (and possibly for saline irrigated lands), strengthened national and devolved capacity to initiate, guide, implement, monitor, and regulate programmes of *carbon sequestration* - whether in soil or in standing crops. Attention particularly to fragile or degraded lands, community-managed forest lands and lands currently subject to shifting cultivation.

(Near-term activity; linked to T.N.C.2, T.N.A.1, E.B.S.1, T.I.S.1)

I.N.S.2: Support - within watershed and agricultural-development programmes - to construct communal, small-scale rainwater-impoundment and livestock-watering facilities, and inter-linkages where appropriate. Guidance and assistance to design and install water-inceptor plots on upland holdings.

(Medium-term activity; linked to T.B.C.1, T.B.L.1, T.N.A.1, I.B.P.1)

I.I.P.1: Strengthening existing institutional capacity, at national, province / state, and irrigation-system level, to formulate, within national water-sector plans, rice-system *irrigation policy* for the near, medium and long terms. Guidance on component policies for *modernization,* operation and maintenance of older systems, within national modernization strategies that are mindful of the concerns for accountability, system-management capability, management incentives and user empowerment, and for equitable treatment for upstream and downstream lands and for those dependent on groundwater and those on gravity-flow water. Assistance in designing and presenting system-modernization training for all irrigated-sector stakeholders.

(Medium-term activity; linked to T.I.C.1, E.B.S.1, I.B.P.1, I.B.S.1)

I.I.S.1: Guidance and capacity strengthening, for all stakeholders, in the ongoing formulation, implementation, and regulation of policies for within-system *irrigation-water allocations* that increase *sustainable* rice-smallholding production. Assistance to define and enact equitable, possibly contentious, systems of water rights and water obligations, and of water markets and water pricing, and of transitional pro-poor safety nets. Strengthening of national and devolved capacity to facilitate the formation and operation of water-users' associations, and to formulate policies that promote and enforce productive farm-level water use.

(Medium-term activity; linked to T.I.C.2, T.I.S.1, E.B.S.1, I.B.P.2, I.B.P.3, I.B.T.1)

In all aspects of *policy* intervention, an FAO (1997d) guideline is apposite: When policy interventions are needed, it is best to look first at changing incentives to encourage behaviour in line with the desired behaviour, and that a key element is that the incentives get the prices right - for prices that reflect the costs to present and future generations. But in situations that require the imposition of controls rather than of incentives, it is worthwhile to recall that FAO and other partners can help mobilize external resources to assist democratic governments to initiate necessary but unpopular policies - including abolition of *"perverse incentives"* - for which the costs of interventions now are likely to be much less than the costs of remedies in Year 2015 and thereafter.

5.5 Outputs and monitoring

Outputs intended and expected from the suggested interventions are several. Those outputs, like the interventions to which they relate, shall be specific to particular countries and provinces / states, depending on those countries' selections from "the menu". The candidate interventions are variously proposed for the near term and for the medium term. However, many of their outputs and impacts on rural hunger, poverty and other livelihood indicators shall be manifest only in the long term, and at different times in different countries and ecozones. Nonetheless, quantifiable progress towards the desired outputs should be detectable in the medium term. Interventions-programme monitoring and evaluation would correspondingly expect to quantify progress towards intended outputs both during and after interventions. It should similarly quantify the synergistic and

added-value benefits that are expected to derive from interactive multi-agency, multi-disciplinary activities and contributions, and from the synergies among technological, institutional, social and human-developmental, and policy and infrastructural interventions.

For all types of rice ecozone, whether irrigated or non-irrigated, interventions would in some countries result in a near-term quantifiable increase in public-sector and perhaps in taxation-induced private-sector *investment in smallholder* agriculture and rural development. Quantitative increases also in public-sector investments in rural infrastructures, connections and communications, and in the numbers of policy, regulatory, and fiscal enactments that together strive to *encourage urban-based* companies to locate employment-generating entities in rural areas. For the irrigated ecozones, there would be expectation of substantive enactments, policies and investments to modernize appropriate irrigation systems.

Enactments also of *pro-smallholder, pro-rural policies,* and identification and amendment / repeal of anti-rural fiscal and taxation policies. There would be complementary, documented, strategies *to replace taxes on labour* by taxes on natural resources; together with legally-enacted and operational procedures and funding for *food-for-work* programmes - for the landless and for the poorest smallholders - that improve the natural-resource base of smallholdings and common properties and that maintain / refurbish communal farm-access roads, jetties, market halls, and irrigation systems. Additionally, crucial and quantifiable enactments, either national or devolved, to strengthen, codify, regularize, and enforce smallholders' rights and obligations of access, tenure, and usage of natural resources and their markets - especially of land and of water. Outputs, also, of legal and regulatory procedures and resources to phase out those *perverse subsidies* that encourage and reward environmental degradation and resource misuse.

Facilitated by those fore-mentioned policies and enactments, pro-rural donor funding would enable quantifiable outputs as strengthened institutions and as newly-constructed or renovated physical structures, infrastructures, and linkages that would support expanded rural micro-enterprises - in production, processing and services. In non-irrigated watershed areas, such structures would include a quantifiable number of rainwater impoundments: the majority of them to supplement local needs for water for crops, livestock, and domestic supply, but some to recharge downstream aquifers.

The definition and development of those fore-mentioned policies - and of the large-scale scale planning and policies for national food production and food security - would be assisted by the suggested intervention to upgrade and make operational and more current the data-analysis procedures to *quantify time trends* in yields and productions.

Interventions to strengthen *rural-support institutions* and service suppliers, and particularly the agricultural-extension institutions and the rural-inputs suppliers, would bring important outputs. Such outputs would be quantified by the numbers of male and of female personnel receiving specialist instruction, and by the increase in knowledge, competence, and confidence of those personnel, and by the improvement in service from inputs suppliers. Quantified additionally by the extent to which that increased knowledge and its associated decision-support methodologies was *acquired and applied* by the rural beneficiaries - notably in their development of micro-enterprises and in their adoption of improved technologies of production and processing.

Correspondingly, multi-agency broad-based *adult education*, and whole-family rice-system-oriented technical and enterprise-management training, and women-specific health / nutrition / maternity *training*, would expect to bring quantifiable near-term benefits in household food security and food safety and in quality-of-life, and quantifiable medium-term impact on the incidence of low birth weights (males and females) and of low body mass index in infant and pre-school females.

Similarly, locally-accessed multi-media information / communications services, and a much-increased number of functional multi-stakeholder user / producer groups and associations, together with accessible micro-finance providers that have adequate data-management systems and procedures to target the very poor, would expect to result in a significant and measurable near-term increase in the numbers of small rural-business formations.

The fore-mentioned policies and the associated economic and social interventions, are complemented by the *technological* interventions proposed for primary production and for value addition. For primary production, quantifiable outputs would be the numbers of location-specific options (and adoptions) for profitable rice-based *crop sequences and mixtures* that are newly made feasible by the interventions-facilitated strengthening

of water, market, and other resources, and by new options for cultivars and their seeds and for sequence-oriented agronomic management.

For irrigated and for favourably-rainfed lowland ecozones, there would be medium-term quantified increase in rice productivity and profitability through adoption of farmer-group *rice-check procedures* to achieve appropriate target yields, and through farmer actions to remedy *quantified yield-gap components*. Correspondingly, for deeper-water and rainfed lowland ecozones: expectation of increased adoption of productive and risk-lessening *pre-monsoon* and *post-monsoon cropping patterns,* including cool-season high-yield rice, using interventions-facilitated cultivar/seed imports and supplies. For upland areas, donor-assisted interventions would expect to initiate and sustain a measurable increased production and sale of *high-value low-bulk* crops and products.

For all rice ecozones, and for rice-system crops, livestock and fish, the more-widespread adoption of *best practices* would be apparent in district-scale productivity statistics. Such adoption would be facilitated by interventions-strengthened extension capacity, local-language manuals and decision-support tools. Prominent among the best practices is the use of high-vigour seeds: interventions would increase measurably the production and use of *such seeds.* Additionally and *vitally*, they would increase the number of *active and profitable community-based* and *women-directed* seed-production-and-marketing enterprises.

Best practices would expect to result also in a favourable increase in the numbers of farmers adopting environment-friendly procedures of balanced and more-efficient crop nutrition, of pesticides application, of water conservation, and of livestock-excreta management. Sustainable resource management and employment creation, would similarly be enhanced if the proposed technological, economic and legal appraisals should justify and help initiate cost-effective programmes for *carbon sequestration* and *bio-fuel production* in some types of riceland.

Outputs from *crops-livestock synergy* would be manifest as an increased competence for such synergy within the national extension services, and quantified increases in rice-farm livestock (and possibly fish) numbers and income. Increases also in synergistic use of products, by-products, and waste products, and in ricefield production of post-rice oil-seed and coarse-grain livestock feeds. Increased numbers and quality of rice and non-rice cultivars, and of breeds of ruminants, poultry and fish, would also quantify sustainable outputs achieved from interventions to promote these synergies; as would *increased protein* content in school-lunch foods and in rural-household diets.

From the technological interventions to increase *post-harvest added value,* outputs would be indicated by increases in numbers of micro-enterprises and of product types - and in rural-community sales - for rice-based and livestock-based food and non-food products; indications also through decreased processing and storage losses. Community-level outputs represented also by enhanced technical competence and by increased numbers of facilities for hygienic processing, preservation, presentation and inspection of meat, egg and dairy products from riceland livestock.

Outputs from the *marketing supports and guidance* that complement the technological and small-infrastructures interventions would be quantified by increased number, variety, and revenues of community-based service-oriented micro-enterprises. Quantified also by more-widespread adoption of an interventions-enlarged set of opportunities for processing, packaging, distribution, and sale of marketable and long-shelf-life food and non-food products from riceland crops, livestock and fish. The required forward-looking extension / training materials would be generated as an output from the interventions-assisted forward planning of farmers' field school curricula.

A medium- and long-term output from the strengthening of institutional capacity to facilitate intra-national and inter-national (WTO) *fair trade* would be that the marketable products from riceland micro-enterprises maintained or increased their share of national and/or global agricultural markets. Additionally, a strengthened influence at WTO would help procure "Green-Box" and other *safety-net protections* for the poorest riceland families.

As was previewed above, the major outputs of rural-livelihoods interventions must be quantified improvements to the *wellbeing* of rural families and communities and to the lessening of their hunger and poverty. Rural families and communities require also a realistic perception and expectation of a brighter future within their rural environs.

However, during this strategy's timeframes, many processes and factors beyond the interventions here proposed shall strongly influence riceland hunger, poverty and wellbeing. Nonetheless, established monitoring / evaluation procedures would permit some assessment of the impacts on those entities of the interventions here proposed. Within those broad entities, assessments would expect to quantify impacts on household incomes, nutrition and empowerment - for smallholder and for landless families; and to quantify impacts also on the productivity of smallholdings and on the profitability of micro-enterprises.

For communities, districts and countries, monitoring of *wellbeing* would be made for various of the outputs specified earlier: notably for increments in rural investment, infra-structural constructions / renovations, and services, for enactments of policy, taxation, and regulatory reforms, for the numbers of new producer groups/ associations, for the aggregate sales by new micro-enterprises, and for the quantity and quality of human-resource development - in institutions and in households and particularly for women.

Monitoring of district- and larger-scale *agricultural-productivity trends* might best be accomplished through analyses of total and single factor productivities and of inputs-use efficiencies, supplemented by determinations of the numbers of adoptions of the more-productive cropping / farming systems and of the high-value / low-bulk-commodity crops that are included among the here-proposed interventions. Monitoring of *natural-resource-system sustainability,* and perhaps of *resilience,* would expect to adopt the procedures used to assess SARM and ILMT programmes.

At *household scale,* monitoring of nutrition, hunger, poverty, wellbeing, and aspirations and expectations would adopt established procedures of baseline and recurrent sampling, and would be structured to disaggregate findings for children and for adults, and for males and for females. In monitoring the profitability of various types of micro-enterprise, and of smallholding activities both individually and in the aggregate, assessment would be made through standard costs/returns procedures.

Operationally, and at all scales, monitoring and evaluation would expect to be *participatory,* and to involve all stakeholders - and notably among them the intended beneficiaries, local and national agencies and civil-society groups, inputs / services suppliers and donors. Procedures would necessarily be country- and perhaps district- and rice-ecozone-specific. They would include multi-stakeholder specifications for progress criteria and indicators, and would feature strengths-and-weaknesses analyses. They would highlight lessons learned and make consequential interpretations and recommendations for adjustments and strengthenings of interventions content and procedure

To the extent possible, the evaluations would quantify also the added-value benefits expected from multi-agency, multi-disciplinary activities, and from the synergies among technological, institutional, human-developmental, and policy and infrastructural interventions.

5.6 Conclusion and follow-through

The preceding text and analyses catalogue the many constraints and challenges to the lessening of rural hunger and poverty, whether generally, or specifically within the Asian rice-based livelihood-support systems. Fortunately, there are many technological, social, economic, institutional, and infrastructural opportunities wherewith to address those constraints and challenges. Encouragingly, recent forecasts for rice-country GDP growth at Year 2003 permit optimism that there can be increased national resources wherewith to help combat hunger and poverty.

Additionally, and as confirmed in the March 2002 Monterrey Consensus and the June 2002 World Food Summit, there is an international willingness and a political and social commitment to provide external resources wherewith to augment those national resources. This commitment derives in part from a strengthening recognition that it is in the interests both of developed and of developing nations to eliminate hunger and poverty, to lessen rural-urban migration, and to manage sustainably the natural and the man-made production resources.

Thus, in addition to the outputs expected from the proposed interventions, it is hoped that this publication shall engender within a knowledgeable and influential readership a heightened and quantitative awareness of the essential features and importance of these vital Asian rice systems. Engendering an awareness particularly of the geographic and human scope of those systems, and of their immense potential to sustain and improve

livelihoods for an increasing population, and to accelerate the progress in lessening the global totals of hungry and poor persons - and especially of hungry and poor children.

It is hoped to strengthen awareness also - in an increasingly globalized and interdependent world - of the economic, social, and environmental significance of the ricelands and of the 3 billion persons who depend upon them for an often-substantial part of their daily food. And within that significance, to emphasize that a food-supply system that is so large and so pro-poor as the rice system has the potential to impact - favourably or adversely - on the world's food security and hence on its politico-economic stability. In which context, it is pertinent that for all concerned, *aid for agriculture* is much preferable both to food aid and to crisis-relief aid.

This publication shall therefore be shared with the many national and international agencies and groups - public-sector, private-sector and civil-society - that constitute the stakeholder community for these Asian rice-based livelihood-support systems. It shall in particular be shared with those several UN agencies that have concern for the alleviation of rural Asia's hunger and poverty - including the International Fund for Agricultural Development and the United Nations Development Programme. It shall be shared also with the Consultative Group for International Agricultural Research and with various of its component International Agricultural Research Centres. It shall be shared with bilateral and multilateral sponsors of programmes of rural development and poverty alleviation, and with the two regionally active development banks: the Asian Development Bank and the World Bank.

Through this sharing, FAO's Regional Office for Asia and the Pacific shall seek responses to the message here presented. Responses shall be sought particularly to determine which of the interventions presented in Sections 5.2 to 5.4 would be priority candidates for incorporation into the national food-security / poverty-alleviation programmes within the major rice-growing countries. There would be complementary enquiry as to the prospects for donor and national-resource support to the proposed strategy, interventions and investments. And enquiry also among the prospective partners in the multi-stakeholder, multi-agency, multi-disciplinary endeavour that is here envisaged.

6. Epilogue

The *Epilogue* to this publication might reiterate that within the Asian rice-based systems there are indeed many challenges and many opportunities as we strive to improve livelihoods - particularly for the poorest of the poor, for hungry children, and for adolescents expecting a brighter future.

On those persons' behalf, we might plead that the required investments are not immense, and that responsible interventions in agriculture and in rural development can help many poor riceland families to use their current assets and strengths to make their own way out of hunger and poverty.

FAO is well positioned to help initiate and support multi-stakeholder rural-livelihoods interventions. Through its sixteen priority areas for inter-disciplinary action - and through the five aggregations from among them that are expressly relevant to Asia's rice systems - FAO can contribute technical, social, economic, institutional, and livelihoods expertise and experience to multi-agency endeavours. To the extent that member countries and sponsors and partner agencies so wish, such interventions and endeavours can be associated with and provide strengthening to the national special programmes for food security.

Through such endeavours and interventions, the world can help provide to the disadvantaged children and adolescents a better quality of life than that experienced by their parents. Notably, immediate interventions can help ensure an adequate physical and mental development for undernourished pre-school children - of whom in East Asia there are 38 millions and in South Asia 86 millions. Crucially, appropriate investments made now may well obviate the need for a later and more-costly crisis management.

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7. References

ADB 1998. Policy on gender and development. 59 pp. Asian Development Bank, Manila, Philippines.

ADB 2000a. Fighting poverty in Asia and the Pacific: The poverty-reduction strategy. 44 pp. Asian Development Bank, Manila, Philippines.

ADB 2000b. Asia recovery report. Asian Development Bank, Manila, Philippines

ADB 2001a. A study of rural Asia: An overview (Beyond the Green Revolution). 187 pp. Asian Development Bank, Philippines.

ADB 2001b. Rural development policy (Draft). 43 pp. Asian Development Bank, Philippines.

ADB 2001c. Asian environmental outlook 2001 (Highlights). 28 pp. Asian Development Bank, Manila, Philippines.

ADB 2002. Asian development outlook 2002 (Highlights). 27 pp. Asian Development Bank, Manila, Philippines

Association of World Council of Churches Related Development Organisations in Europe (APRODEV) 1999. John Madeley (ed.) Trade and hunger: How international trade is causing hunger. Brussels, Belgium.

BCEOM 2000. Conservation of Segara Anakan biodiversity. 36 pp. BCEOM Consultants, Jakarta, Indonesia.

CSD 1997. Cropping systems in India, 9 pp. Cropping Systems Directorate, ICAR, Meerut, India.

CIMMYT 2000a. Pakistan puts aside the plough. CIMMYT Wheat Programme: Internet reports at May and October 2000. International Maize and Wheat Research Centre, Mexico.

CIMMYT 2000b. Will Asia's appetite for maize exclude the rural poor? CIMMYT Maize Programme: Internet report at October 2000. International Maize and Wheat Research Centre, Mexico.

Dixon, J, Gulliver, A, and Gibbon, D. 2001. Farming systems and poverty. 357 pp. FAO (Rome, Italy) and World Bank (Washington DC, USA).

Dobermann, A, Langner, H, Mutscher, H, Skogley, E.O, Neue, H.U, Yang, J.E, Adviento, M.A, and Pampolino, M.F. 1994. Nutrient adsorption kinetics of ion-exchange resin capsules. *Soil Science and Plant Analysis*, **25:** 1329-1353.

Dobermann, A, Sta Cruz, P.C, and Cassman, K.G. 1996a. Fertilizer inputs, nutrient balance, and soil-nutrient-supplying power in intensive, irrigated rice systems. I. Potassium uptake and K balance. *Nutrient Cycling in Agroecosystems*, **46:** 1-10.

Dobermann, A, Cassman, K.G, Sta Cruz, P.C, Adviento, M.A, and Pampolino, M.F. 1996b. Fertilizer inputs, nutrient balance, and soil-nutrient-supplying power in intensive, irrigated rice systems. II. Effective soil-K-supplying capacity. *Nutrient Cycling in Agroecosystems*, **46:** 11-21.

Dobermann, A, Pampolino, M.F, and Adviento, M.A. 1997. Resin capsules for on-site analysis of soil-nutrient supply in lowland rice fields. *Soil Science Society of America Journal*, **61.**

Dobermann, A, and Fairhurst, T. 2000. Rice: Nutrient disorders and nutrient management. 191 pp. Potash and Phosphate Institute (Singapore) and International Rice Research Institute (Philippines).

FAO 1990. Caloric requirements. FAO (Rome, Italy).

FAO 1991. Rice-husk gasification technology in Asia. RAP Publication 1991/02. FAO (Bangkok, Thailand)

FAO 1997a. Modernization of irrigation schemes. RAP Publ'c'n 1997/22. FAO (Bangkok, Thailand)

FAO 1997b. Rice products in Asia. RAP Publication 1997/38. FAO (Bangkok, Thailand).

FAO 1997c. Rice by-products in Asia. RAP Publication 1997/39. FAO (Bangkok, Thailand).

FAO 1997d. Guidelines for integration of sustainable agricultural and rural development into agricultural policies. FAO Agricultural Policy and Economic Development Series 4. FAO (Rome, Italy).

FAO 1998a. The state of food and agriculture: 1998. FAO (Rome, Italy).

FAO 1998b. Poverty alleviation and food security in Asia: Lessons and challenges. RAP Publication 1999/01. FAO (Bangkok, Thailand).

FAO 1998c. Guide to efficient plant-nutrition management. 19 pp. FAO (Rome, Italy).

FAO 1999a. Nutritional security: Asian perspective beyond 2000. Working Paper Series 1/1. FAO (Bangkok, Thailand).

FAO 1999b. Poverty alleviation and food security in Asia: Land resources. RAP Publication 1999/02. FAO (Bangkok, Thailand).

FAO 1999c. Poverty alleviation and food security in Asia: Role of livestock. RAP Publication 1999/02. FAO (Bangkok, Thailand).

FAO 1999d. Improvement of efficiency of nitrogen fertilizers. Final Technical Report, Project RAS/ 156/JPN. 44 pp + appendices and map. FAO (Rome, Italy).

FAO 1999e. The strategic framework for FAO: 2000-2015. 59 pp. FAO (Rome, Italy).

FAO 1999f. Handbook series: Vol. I: Overview. Special programme for food security. 39 pp. FAO (Rome, Italy).

FAO 1999g. Modernization of irrigation-system operations. RAP Publication 1999/43. FAO (Bangkok, Thailand).

FAO 2000a. Medium-term plan 2002-2007. 31 pp. FAO (Rome, Italy).

FAO 2000b. Selected indicators of food and agriculture development in the Asia-Pacific Region: 1989-99. RAP Publication 2000/15. FAO (Bangkok, Thailand).

FAO 2000c. Bridging the rice-yield gap in the Asia-Pacific Region. RAP Publication 2000/16. FAO (Bangkok, Thailand).

FAO 2000d. Agriculture: Towards 2015/2030. Technical Interim Report. FAO (Rome, Italy).

FAO 2000e. FAO rice information: Volume 2. 201 pp. FAO (Rome, Italy).

FAO 2000f. The state of food and agriculture: 2000. FAO (Rome, Italy).

FAO 2000g. Proposed farming systems study for World-Bank rural-development strategy. Working documents. FAO (Rome, Italy).

FAO 2000h. The state of food insecurity: 2000. 32 pp. FAO (Rome, Italy).

FAO 2000i. Agricultural trade in Asia and the Pacific: Overview for workshop *on* Uruguay round and multilateral trade negotiations. 29 pp. FAO (Bangkok, Thailand).

FAO 2001a. Global farming systems study: Challenges and priorities to 2030. Global regional analysis - East Asia and Pacific. Consultation document (by D. Ivory). FAO (Rome, Italy).

FAO 2001b. Selected indicators of food and agriculture development in the Asia-Pacific Region:1990-2000. RAP Publication 2001/17. FAO (Bangkok, Thailand).

FAO 2001c. Agenda notes for July-2001 meeting of inter-government groups on commodity problems. 24 pp. FAO (Rome, Italy).

FAO 2001d. The state of food and agriculture: 2001. FAO (Rome, Italy).

FAO 2001e. FAO rice market monitor: Vol. 4 No. 4. FAO (Rome, Italy).

FAO 2001f. Consultation on yield gap and productivity decline in rice. 53 pp. FAO (Rome, Italy).

FAO 2001g. Crop diversification in the Asia-Pacific Region. RAP Publication 2001/03. FAO (Bangkok, Thailand).

FAO-NGO 2000. Deccan Development Society, in "Empowering women, and human values". 96 pp. FAO-NGO South Asia Programme, New Delhi, India.

FAS 2000. Estimating and forecasting crops at USDA. Foreign Agricultural Service of the United States Department of Agriculture. FAS-online, May 2000.

Fei, H. 1987. Rice-wheat cropping systems and their techniques. Proc. 18th Asian Rice-Farming Systems Network, pp. 171-184. International Rice Research Institute, Philippines.

Guerra, L.C, Bhuiyan, S.I, Tuong, T.P, and Barker, R. 1998. Producing more rice with less water from irrigated systems. SWIM Paper 5. 19 pp. International Water Management Institute, Sri Lanka.

Guo, Y. 1989. Rice-wheat cropping systems in China. Proc. 20th Asian Rice-Farming Systems Network, pp. 201-226. International Rice Research Institute, Philippines.

Huke, R.E, and Huke, E.H. 1982. Rice area by type of culture. International Rice Research Institute, Philippines.

Huke, R.E. 1996. Digitized maps of rice area by type of culture. International Rice Research Institute, Philippines.

Huke, R.E, Huke, E.H, Woodhead, T, and Jikun Huang. 1993. Rice-wheat atlas of China. 37 pp. International Rice Research Institute, Philippines.

Huke, E.H, Huke, R.E, and Woodhead, T. 1993a; Rice-wheat atlas of. Bangladesh. 32 pp. International Rice Research Institute, Philippines.

Huke, R.E, Huke, E.H, and Woodhead, T. 1993b. Rice-wheat atlas of Nepal. 30 pp. International Rice Research Institute, Philippines.

IFAD 2001. Rural Poverty Report: 2001. 265 pp. International Fund for Agricultural Development, Rome, Italy.

IFDC 1999. Report of urea-briquettes programme in Bangladesh. International Fertilizer Development Centre, USA.

IFPRI 1995a. Growth, and poverty alleviation. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1995b. Ecoregional perspective on mal-nutrition. 4 pp. 2020 Vision Brief 14. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1995c. Water scarcity. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1996. World trends in fertilizer use. 3 pp. 2020 Vision Brief 38. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1998a. Report of a South Asia Vision-2020 workshop. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1998b. The East-Asia economic crises and the poor. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1998c. Investing in poverty reduction and new export opportunities. 4 pp. 2020 Vision Brief 56. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1998d. Crop losses to pests. Internet report at February 2001. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1998e. Wheat technologies. Internet report at February 2001. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1999a. Growth, poverty alleviation, and the environment. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 1999b. India's cereals: Production and demand. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 2000a. Child malnutrition. Internet report at October 2000. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 2000b. Technologies for the South-East Asian uplands. 3 pp. 2020 Focus 4: Brief 4 of 9. International Food-Policy Research Institute, Washington DC, USA.

IFPRI 2000c. Liberalization of the rice market in Viet Nam. Report by the International Food-Policy Research Institute, Washington DC, USA.

IFPRI 2001. Micro-finance: A pathway from poverty: Summaries of findings, 1994-2000. International Food-Policy Research Institute, Washington DC, USA.

Indonesia 2000. Statistical year book of Indonesia 1999. Central Bureau of Statistics, Government of Indonesia, Jakarta.

IRRI 1994. Annual report for 1993. International Rice Research Institute, Philippines.

IRRI 1997. Rice almanac, Second edition. 181 pp. International Rice Research Institute, Philippines.

IRRI 2000. Programme report for 1999. International Rice Research Institute, Philippines.

IRRI 2001a. Internet report at mid-2001. International Rice Research Institute, Philippines.

IRRI 2001b. IRRI 2000-2001: Rice research: The way forward. 71 pp. International Rice Research Institute, Philippines.

IRRI-IFAD 2000. Rainfed rice - A sourcebook of best practices. (IRRI, IFAD, ICAR, IIRR).

IWMI 2000a. Global water scarcity study, pp. 9-17 *in* Annual report 1999-2000. International Water Management Institute, Sri Lanka.

IWMI 2000b. Waste-water use. Internet report at February 2001, 4pp. International Water Management Institute, Sri Lanka.

IWMI 2000c. Water-saving irrigation techniques, pp. 27-35 *in* Annual report 1999-2000. International Water Management Institute, Sri Lanka.

IWMI 2001. Annual Report 2000-2001. International Water Management Institute, Sri Lanka.

Husain, A.M.M, Hossain, M, and Janaiah, A. 2001. Hybrid rice adoption in Bangladesh. BRAC research monograph series No. 18. 45 pp. Dhaka.

Kijne, J.W, Prabakhar, S.A, Wopereis, M.C.S, and Sahrawat, K.L. 1998. How to manage salinity in irrigated lands. SWIM Paper. 44 pp. International Water Management Institute, Sri Lanka.

Lacy, J.M. 1998. Learning from farmers - the check approach. Pp 58-65 *in* Proceedings of the Ninth Australian Agronomy Conference.

LEAD 1999. Livestock, environment, and development initiative: Livestock and environment toolbox. (*Via* internet). European Commission and FAO (Rome, Italy).

Molden, D. 1997. Accounting for water use and productivity. SWIM Paper 1. International Water Management Institute, Sri Lanka.

Paroda, R.S, and Kumar, P. 2000. Food production and demand in South Asia. *Agricultural Economics Research Review* 13**:** 1-24.

Rice-Wheat Consortium 2000a. Bed-planting systems. 3pp. Internet report at February 2001.

Rice-Wheat Consortium 2000b. Easing farmers' burden in Nepal (3 pp), and Whole-family wheat-management training in Bangladesh (3pp). Internet report at February 2001.

Rice-Wheat Consortium 2000c. Post-rice wheat in Pakistan. Internet report at February 2001.

Siddiq, E.A. 2000. Productivity decline in rice-production systems. 49 pp. (FAO, Rome, Italy).

Singh, R.B. 1997. Strategies and prospects to sustain rice production. 28 pp. FAO-RAP working paper. FAO (Bangkok, Thailand).

Singh, R.B. 2001a. A hunger-free India: Presidential address to the Agricultural-Science Section of the Indian Science Congress. Indian Agricultural Research Institute, New Delhi.

Singh R.B. 2001b. Science for sustainable food security, nutritional adequacy, and poverty alle-viation in the Asia-Pacific Region. 73pp. Working draft. FAO (Bangkok, Thailand).

Singh, R.B, Kumar, P, and Woodhead, T. 2002. RAP Publication: 2002/03. 54 pp. FAO (Bangkok, Thailand).

Singh, R.B. and Houtman, R. 2002. Policy, regula-tory framework, and other support services for micro-finance. FAO Bangkok, Workshop paper.

Singh, R.B, and Paroda, R. 1994. Sustainability and productivity of rice-wheat systems in the Asia-Pacific Region. Pp. 1-35 *in* RAP Publication 1994/11. FAO (Bangkok, Thailand).

Steinfeld, H, de Haan, C, and Blackburn, H. 1997. Livestock-environment interactions: Issues and opportunities. 300 pp. European Commission (Brussels), FAO (Italy), and World Bank (Washington), and various OECD governments.

Tucker, N, and Johnson, M. 2001. Engineers and farmers combine to make plastic car parts from elephant grass. 3pp. Internet report at June 2000. University of Warwick, UK.

UK / DFID 2000. Eliminating world poverty: Making globalisation work for the poor. 108 pp. Department for International Development, UK.

UK / DFID 2001. Sustainable livelihoods: Building on strengths. 8 pp. Department for International Development, HM Government. London, UK.

UNICEF 2000. State of the World's Children: 2000. 122 pp. United Nations Children's Fund. New York, USA.

UNICEF 2001. State of the World's Children: 2001. 116 pp. United Nations Children's Fund. New York, USA.

Wang, L, and Guo, Y. 1994. Rice-wheat systems and their development in China. Pp. 160-171 *in* RAP Publication 1994/11. FAO (Bangkok, Thailand).

Woodhead, T, Huke, R.E, and Huke E.H. 1993a. Rice-wheat atlas of Pakistan. 32 pp. International Rice Research Institute, Philippines.

Woodhead, T, Huke, R.E, and Huke E.H. 1994. Areas, locations, and ongoing collaborative research for the rice-wheat systems of Asia. Pp. 68-96 *in* RAP Publication 1994/11. FAO (Bangkok, Thailand).

Woodhead, T, Huke, R.E, Huke, E.H, and Balababa, L. 1994. Rice-wheat atlas of India. 147 pp. International Rice Research Institute, Philippines.

World Bank 2001a. Rural development strategy: Reaching the rural poor. Internet drafts at July and August 2001. World Bank, Washington DC, USA.

World Bank 2001b. Globalization. Internet draft at November 2001. World Bank, Washington DC, USA.

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