to cause violent undulations in food production. Consequently, different parts of the world went through cycles of famine. Even today, the food situation is precarious with only a few countries in the world having surplus grains to offer either on commercial or concessional terms. A new dimension of complexity has been added by the ever escalating cost of energy. Thus, although food occupies the first position among the hierarchical needs of man, a global food security system is yet to emerge. It is in this context that the rapid development of strong and enduring national food security systems assumes urgency. As the Roman philosopher Seneca said "a hungry people listens not to reason nor cares for justice, nor is bent by any prayers". President Kenneth Kaunda rightly remarked while delivering the McDougall Lecture of F.A.O. in November 1979, "Hungry people everywhere now want to eat today and not tomorrow". Agricultural development is hence a must not only for meeting the food requirements of the expanding human population but for socio-political stability and for peace on earth. I have therefore chosen the topic "Agricultural Growth and Human Welfare" for this series of lectures instituted in the memory of three of the greatest visionaries and humanists of our times - Dr. J.E. Kwegyir Aggrey, Rev. A.G. Fraser and Sir Gordon Guggisberg. To start with, I would like to deal with the agricultural balance-sheet, first dealing with assets and then with liabilities.

II. Agricultural Balance Sheet: Assets

His Excellency Dr. Hilla Limann, the President of Ghana, while launching the Crash Programme for Agricultural Development on 14th May, 1980, stressed the fact that Ghana is blessed with rich natural endowments. In the words of the President, "Our rich variety of arable lands, soil, seasons and geographical zones and our enormous water resources are the envy of others even within our own

West African sub-region. Yet those others seem rather to produce more crops and livestock and are able to sell some of them to us. If vegetables and even flowers can now be grown in arid, even desert wastes, why can we not grow the same crops in our more fertile, wetter and lush country?"

The New Deal for agricultural production launched last year in Ghana rightly lays stress on the urgent need "to arrest and eventually reverse the past strange phenomenon of food shortages". In his address the President of Ghana has outlined a comprehensive strategy for converting the natural assets of the country into wealth meaningful to its people. The action programme for agricultural production in Ghana during 1981 presented by Dr. E.K. Andah, Minister for Agriculture, spells out the areas requiring immediate action and the constraints which need to be removed in order to bridge the gap between potential and actual farm yields(2). Given a right blend of political will, professional skill and peoples action, I have little doubt that the desire of the Government to make hunger a problem of the past will become a reality soon.

I feel that the starting point for any action plan is a clear understanding of the developmental assets and liabilities of each area. I would hence like to deal with the conceptual aspects of a balance-sheet preparation in the field of agricultural development.

(a) Human resources: The most important asset for any country is its human population. Poverty persists under conditions where the human resource is under-valued and land, buildings and other physical resources are over-valued. Ghana is fortunate in its human resource. F. Agbodeka, for example, describes in the following words how the farmers of Ghana brought about the great progress in cocoa cultivation (3).

> "The amount of energy and enterprise displayed in this work all over the country was amazing;

and all eyewitnesses including the Curator of Botanical Gardens and officials from D.Cs. (district commissioners) right up to the Governor himself could not but admire the Gold Coast farmers who, single-handed, brought about this fantastic agricultural revolution."

The human resource can give its best only under conditions of equality of opportunity to every child for the realisation of his or her innate genetic potential for physical and mental development. It is in this context that we should recall with gratitude the work of Sir Gordon Guggisberg who, in his 1925 educational plan, stressed so much on primary education, the building up of high quality teaching staff and the provision of equal educational opportunities for boys and girls. The edifice of economic development can be erected only on the foundation of human resource development through the provision of basic human needs in nutrition, health care, education, environmental sanitation and employment.

(b) Sunlight: We all live on this earth as guests of the green plants which are able to utilise sunlight directly and convert it into products of value to man. Every second the sun sends into space radiant energy equivalent to about 1 million times that of the earth's coal, petroleum and natural gas supplies before these were tapped by man. The earth, however, intercepts only a very small fraction of this energy. The earth receives approximately 40×10^6 kcal of broad spectrum of radiant energy per hectare of land per day. Under normal agricultural practices, the efficiency of energy conversion in crop plants varies from 0.1 to 1.0 per cent. Thus, only a very small percentage of solar energy is being stored up in the food material during the photosynthetic process of green plants. The poor energy conversion rate in green plants can be compared with the early model of steam engine invented by James Watt in which efficiency of energy conversion from coal was very low. But in the modern diesel engine the energy conversion rate can exceed 40 per cent. Some improvement in solar energy conversion can be effected by improving agricultural practices. The energy conversion rate can easily be doubled by introducing known agricultural technology under intensive cultivation. Under special conditions increase in energy conversion rate as high as 6 to 10 per cent from its initial level of 0.1 to 1.00 per cent has been reported. On theoretical grounds the maximum efficiency of energy conversion is believed to be as high as 25 to 30 per cent. There is thus much scope for innovative research in this field.

For an efficient harvest of sun throughout the year, it is essential that we cover every available piece of vacant land with annuals as well as perennial shrubs and trees. The photosynthetic pathway of development presents a feasible method of coupling human resource with sunlight through the medium of green plants. We now know that this pathway is just not merely the source of providing food, fodder, fuel, fibre, etc. but also a potent source of various forms of energy. Therefore, every country will have to develop a strategy, of solar energy utilisation through the photosynthetic pathway resulting either in products of direct value to man or as a source of biomass leading to a variety of renewable energy produce. Biomass can be utilised directly as a fuel or can be converted into alcohol, methane, ammonia, etc. through suitable bio-chemical and micro-biological methods. The vast panorama of opportunities available in biomass utilisation is just unfolding (Fig. 1). Energy plantations based on the cultivation of "Firewood Crops" will hereafter become as sophisticated an art as the cultivation of rice or wheat. A recent publication by the U.S. National Academy of Sciences lists some of the important firewood crops, which in the case of leguminous species can also provide fodder, feed and fertilizer in addition to fuel (4).

Besides the photosynthetic and photosynthesis-cum-pyrolosis pathways of solar energy use, there are other areas of application of sunlight such as thermal, thermodynamic and photovoltaic energy which are exceedingly important in the field of agriculture. Photo-thermal applications are already widely adopted in villages for dehydration of perishable commodities, preparation of salt from sea water, solar distillation, etc. Through appropriate devices, it is now possible to improve the efficiency of solar thermal applications in cooking of food, heating of water, drying of products, distillation and desalination.

The other emerging use of solar energy is in getting it converted into electricity by means of semi-conductor devices referred to as solar photo-voltaic cells. Solar photo-voltaic systems are currently under development in several countries and they could provide an important source of energy for purposes such as pumping ground water for irrigation, space heating and cooling and refrigeration. Solar photo-voltaic systems can be suitably integrated with other sources of renewable energy such as biomass and fuel wood plantations. Thus solar energy and other renewable sources like hydel, wind and nuclear power offer the most exciting methods of overcoming the difficulties that will confront us when fossil fuel reserves dry up. The problems created by using up the fossil fuel reserves generated by past photosynthesis can be faced successfully by taking better advantage of current photosynthesis. This will be the real green revolution.

(c) <u>Soil</u>: The third major agricultural asset is soil. Of the eleven recognized ecological zones of Africa viz. Guinean, Sudanian, Sahelian, Saharan, Eastern, Zambesian, Transvalian, Kalharian, Karro-Namaqualian, Basutolian and Medagascaran, our interest in West Africa lies in the Sahelian, Sudanian and the Northen Guinean Zones. Primarily based on rainfall and altitude, broadly six ecological zones can be distinguished in Africa. They are:

a) Lowland moist forest zone in areas having over 1400 mm. of rainfall and lying mostly below 600 meters;

b) Lowland savanna with rainfall between 400-1400 mm. per annum and altitude below 600 meters;

c) Highland savanna with the same rainfall as lowland savanna but altitude between 600-1000 meters;

d) High montane zone with rainfall above 800 mm. per annum and altitude above 1000 meters (Except for areas above 2000-2500 and over meters, the vegetation and ecology are mostly like the high land savanna. But above 2000-2500 meters and over, the rainfall is above 1400 mm. and often meet with high forests);

e) Steppe and desert zone areas with less than 400 mm of annual rainfall and below 600 meters; and

f) Mediterranean zone with annual rainfall of 800-1400 mm and lying beyond 30° latitude.

All these zones have distinct soil characteristics. The World Soil Resources Report of F.A.O. contains detailed data on the production potential of different soil and agro-ecological zones in Africa (5).

(d) Water: The President of Ghana in his address on the new deal for agricultural production said: "We cannot depend on rainfall alone for the success of the plans for increased and, especially, sustained agricultural production since rains have often been unseasonable and failed us in the past. Irrigation, shall, therefore, necessarily play a vital role in our efforts in this field: maximum use shall start to be made of all available irrigation facilities for the cultivation of rice, vegetables and tomatoes, especially, during dry seasons, in order to curtail seasonal shortages of these items" (2). A dependable source of water supply is necessary both to elevate and stabilise crop production. There are 4 major sources of irrigation which deserve detailed attention:

a) Conservation and effective utilisation of rain water through appropriate water harvesting and watershed management procedures;

b) Exploration and use of ground water sources with particular attention to the enrichment and scientific management of the aquifer;

c) Harnessing surface water resources through major, medium and minor irrigation projects including lift irrigation;

d) Inter-basin transfer of water at national and regional levels so as to utilise water which otherwise would have gone into the sea;

e) Solar desalination of sea and brackish water for human, animal and agricultural uses.

Every country will have to develop an appropriate irrigation strategy based upon the available rain, surface and ground and sea water resources. On farm management of water deserves as much attention as the creation of irrigation facilities.

(e) Flora: The ecological diversity of a country is reflected by its native flora and fauna. Many of the crop plants cultivated in Ghana like Sorghum and Millet and several tubers are of African origin. Others like rice and maize are either from the old or the new worlds. Cocoa which is such an important component of the Ghanaian economy is one of the many crops first domesticated in Mesoamerica. Before the arrival of Europeans the tree grew wild throughout the New World tropics and the art of cultivating it was known only in Mexico and Central America. Domestication was achieved by the native people who lived in the region between the present border of Guatemala with Mexico ...

and the Atlantic coast. Archaeological remains, of possible Mayan origin, have been found in Gautemala which show pods of "cacao lagarto". This variety may have been the first kind to be domesticated because of its soft husk and well-flavoured seeds. In Mexico the same kind of cocoa is illustrated in ancient inscriptions, and its importance in religious ceremonies may be deduced from stone carvings of the Totonaca culture in Veracruz, which date from the 5th to the 9th century A.D. The preparation of chocolate from cocoa beans is a complex process which the first Spanish invaders learnt from the Aztecs. In Aztec culture the use of chocolate was restricted to the upper classes of society. The Spaniards adopted the use of chocolate to which they added sugar and spices and they extended the cultivation of cocoa trees to South America. Cultivation was subsequently spread to Africa and south-east Asia. In Central America cocoa production gradually declined to such an extent that during the latter part of the Spanish colonial era cocoa beans were rare enough to be used as money. There have been changes in varieties, and high quality cultivars, such as the "Criollos", but which were susceptible to disease have almost disappeared. They have been replaced by South American cultivars which are more disease resistant and give higher yields. That an introduced crop should have assumed such economic importance in an adopted home that a separate Ministry of Cocoa Affairs exists in Ghana, indicates the great role of plant introduction in recent agricultural history.

As pointed out again by Sir Gordon Guggisberg in 1919: "We have all our eggs in one basket. The cocoa baskets are full - what about the other baskets if anything goes wrong with the cocoa crop or the cocoa market?" We are all familiar with the wisdom underlying this statement. We find from recent economic history that it is only countries which have diversified their home market and export earning base that are able to withstand the problems arising from the "bust and boom cycle" met with in the case of several natural products in national and international trade. Malaysia exemplifies the wisdom of such a diversification process. For example, starting originally only with natural rubber and timber, Malaysia has now become the world's leading producer of palm oil and has also a dynamic programme of coconut-cocoa inter-culture. Coupled with deposits of tin and petroleum reserves, the Malaysian economy, therefore, has a blend of renewable and non-renewable wealth which confers upon it the kind of resilience necessary to prevent undue hardship to people in periods of global economic recession.

(f) Fauna - Ayensu (6) has described how Africa is a biological treasure house of valuable animal species. "Throughout the history of Africa, the utilisation of wildlife as a major source of meat protein has been significant. However, traditional hunting practice has led to a decrease in the populations of some of the choice game meats. In Ghana, for example, meat of the grasscutter (*Thryonomys swinderianus*) seems to get more and more expensive in the local open markets even if its availability seems to be quite normal. In fact, it has been observed that the more the supply of the grasscutter meat in the city markets, the higher the price. This observation simply means that the supply of this particular bushmeat is not meeting consumer demand. There are several species of game animals that have proven to be good protein sources. In East Africa game animals such as the eland, impala, zebra, wildebeest, giraffe, duiker, warthog, steenbuck, waterbuck, buffalo, bush pig, elephant and kudu feature daily in the diets of many people. One of the game reserves, I am familiar with, is the Mole National Park in Ghana. The game animals I encountered there include hartebeest, buffalo, waterbuck, roan antelope, kob, bushbuck, oribi, duiker, warthog, baboon, patas monkey and green monkey. All these animals constitute substantial sources of protein if their numbers are allowed to swell and then cropped." The conservation and scientific management of the native fauna would help to make this natural resource an invaluable economic asset. In addition, cattle, sheep, goat and poultry constitute important sources of income and nutrition in the livestock sector.

(g) Energy: As in other developing countries, commercial energy constitutes only a portion of the total energy used in agriculture and in rural areas. The F.A.O., for example, has estimated the share of commercial energy in agricultural production in different parts of the world (Table I). The developing countries of the world consume only a small proportion of the total energy used in the world (Fig.2), which in turn is partly responsible for low agricultural and industrial productivity. A beneficial fall out of this escalating cost of fossil fuels is the greater scientific attention that renewable forms of energy now receive. Energy management will hold the key to sustained agricultural advance and hence, based on local possibilities, integrated energy supply systems based on the economic use of all available forms of energy will have to be developed for each agro-ecological area.

Table 1 - Commercial energy use in agricultural production 1/ and share of each input, developing market economies 1980 and projections for 2000

	Total		Fertilisers		Farm machinery		Irrigation		Pesticides	
	1980	2000	1980	2000	1980	2000	1980	2000	1980	20
	Million tons oil equivalent		................%.......................							
Africa	1.9	12.1	36	46	49	48	7	2	9	4
Far East	16.4	93.1	62	70	16	23	19	5	3	1
Latin America	12.4	48.7	47	40	46	57	4	2	3	2
Near East	6.1	20.6	43	50	36	40	19	8	2	2
Developing market economies 2/	36.8	174.5	53	58	32	12	4	3	2	

Source: Based on preliminary data from revised normative scenario (unpublished) of FAO's study of Agriculture: Toward 2000.

1/ Crops and Livestock only

2/ 90 countries accounting for 98% of population of developing world outside China.

III. AGRICULTURAL BALANCE-SHEET : LIABILITIES

The agricultural liabilities of every country can be classified into two major categories - man-made and natural. The natural liabilities largely relate to the inherent properties of soil, water and climate. What is, however, more serious is the damage being caused to basic life support systems either intentionally or unintentionally by the human population. The growing destruction of our ecological endowments is partly the result of demographic pressures. The genuine needs of the poor for fuel and fodder and the greed of the rich for exploiting forests for commercial and industrial purposes both contribute to eco-destruction. In a report to the President of the United States on "Global Resources, Environment and Population," there is a vivid description of the kind of world we are likely to witness at the beginning of the next century, in case the current trends of damage to soil and water, flora and fauna and the environment continue. The Global 2000 Report depicted a world "more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now." It projected that world population would increase from 4 billion to 6.35 billion in just one-quarter of a century; that the gap between rich nations and poor would widen; that per capita food consumption would rise somewhat worldwide - but would not improve materially in the poor countries of South Asia and the Middle East, and would decline disastrously in Sub-Saharan Africa; that the real cost of food would rise everywhere; that the real cost of fuels would also rise everywhere and that fuelwood would fall far short of need; that many currently productive grasslands and croplands would turn to desert-like conditions; that as much as 40 per cent of the world's remaining tropical forests would be lost; and that as many as 20 percent of the species of plants and animals now inhabiting the earth could be extinct -- all by the end of the century (7).

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The Report noted that the burning of fossil fuels is already causing damaging increases in the acidity of rain and snowfall, and it is raising the concentration of carbon dioxide in the earth's atmosphere. Continued into the next century, rising CO_2 levels could cause a warming of the earth sufficient to alter substantially the world climate -- with possible serious disruption of human activities, especially agriculture.

These findings and conclusions are a description of what may be expected if present trends continue. They are not predictions of what will occur, but projections of what could occur if the nations and people of the world do not respond to their warnings.

Resource impoverishment, environmental degradation and soaring population growth have not just been discovered for the first time as global problems. All nations have long recognised them and made serious efforts to deal with them. The United Nations Environment Programme has in particular been drawing attention to the need for arresting further damage to natural eco-systems. While awareness and analysis are improving, commensurate action is conspicuous by its absence, particulary in poorer nations. This is where the prophets of doom serve a positive purpose by generating a " do or die" atmosphere.

In the past decade, a great deal of international attention has been focussed on whether global supplies of finite nonrenewable resources, especially oil and gas, can continue to be used in an exponential manner. The U.S. report stresses the need to maintain the productivity of the earth's systems -- the air and water, the forests, the land -- that yield food, shelter, and the other necessities of life. These resources are renewable if they are kept in a condition of health. But they are

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susceptible to disruption, contamination, and destruction. Even agriculture which is the most important source of renewable wealth can be made no different from non-renewable sources of weath if desertification continues.

In some areas, such as sub-Saharan Africa and South East Asia, a vicious cycle of poverty, accelerating population growth, and erosion of the resource base are visible. Here, the earth's capacity to support life is being seriously damaged by the efforts of present populations to meet their immediate needs, and the damage threatens to become worse. People who have no other choice for getting their living plant crops on poor soils that will soon wash away, graze their stock on land that is turning to desert from overuse, cut trees that are needed to stabilise soils and water supplies, burn dung needed to fertilize and condition agricultural soils. According to World Bank, some 800 million people to-day are trapped in conditions of "absolute poverty," their lives dominated by hunger, ill health, and the absence of hope. So long as their situation does not improve, trends toward impoverishment of the earth's renewable resource base are likely to worsen, making the plight of the poor even more desperate. There is therefore an immediate need for every poor nation developing a "Basic Human Needs" programme designed to provide every rural family in the country the minimum essential requirements of water, food, fuel, fodder, fertilizer and work. The Basic Human Needs programme and the Agricultural Development programme will have to be developed in a mutually supportive nature.

These stresses, while most acute in the developing countries, are not confined to them. For example, in recent years the United States has been losing over 1 million hectares of rural land annually -- including about 400,000 hectares of good agricultural land -- due to the spread of housing colonies, highways, shopping centres, and the like. Each year U.S.A. is also losing the equivalent, in production capability, of as much as 400,000 hectares due to soil degradation -- erosion and salinization. The Global 2000 Report emphasized the serious worldwide nature -- in rich countries as well as poor -- of the degradation and loss of agricultural land. Pollution of water supplies by toxic chemicals and the physical destruction or pollution of essential habitat for fisheries are also common threats to natural systems throughout the world.

It is hence essential that every country takes steps to avoid the diminution or destruction of the biological potential of land caused by man-made factors. For this, each component of the eco-system will need both separate and integrated attention.

(a) Soil - An assessment of the suitability of soil for different land uses should take into consideration the factors which limit soil fertility and cause erosion and water logging. If appropriate soil management measures are not adopted rapid soil degradation would result. Out of the total land area of about 22 million hectares in Ghana, about 18 million hectares are susceptible to erosion hazards, 15 million hectares to soil fertility factors and over 6 million hectares to wetness factors. These figures serve the purpose of highlighting the importance of proper soil management to be adopted in the future, especially in view of the fact that the fallow period will have to be reduced considerably on a large part of the cultivated area. Contour strip cultivation and contour terracing coupled with a well selected crop rotation would help in reducing the fallow period. There are also areas in the valley bottoms and in the flood plains where it is not necessary to rely so heavily on soil conservation measures as in the uplands. These areas could be opened up more for crop production, as is already being done for large-scale mechanized rice production in the Northern Region of Ghana (8).

During the last 20 years - from 1957 to 1977 - the area of arable land increased by 135 million hectares, that is about 9 percent of to-day's total 1.50 billion hectares of cultivated land in the world. During the same period, the world's population has increased from 2.8 to 4 billion, that is by 40 percent. In terms of increased production, the increase in arable land at a low level of agricultural inputs would have sufficed only to feed an additional 400 million people. The food supplies for the 800 million additional people have been obtained from an intensification of agriculture on land already cultivated, reflected by a spectacular increase of fertilizer use - from 24 million tons of plant nutrients in 1957 to 88 million tons in 1976/1977 - and a considerable expansion of irrigation. It is significant, however, that of the 135 million hectares added arable land, 70 percent was opened in developing countries while intensification of production took place in industrialized countries which consumed 85 percent of the world's fertilizer production.

The additional production resulting from extension of cultivated land in developing countries is lagging far behind that required by the increase of population. Although global estimates of land resources indicate the presence of large tracts of potentially arable land, they hardly permit concrete and practical conclusions with regard to prospects for future trends. Dudal (9) has hence stressed the urgent need to qualify the concept of "arable land" in respect to: specific types of land use, production potential, technical and financial inputs which are required, hazards of soil degradation which may occur and the location of the lands still available. Furthermore, global estimates have to be complemented by land evaluation at the country level since different countries vary greatly in their land resources endowment, and limitations of transportation are often obstacles to massive transfers of food products from one area to another. The solution of the world food problem requires that each community uses its land to its best advantage. It has been rightly stated, "the use of land is a down - to - earth index of a civilization, for land has been a silent partner in the rise and fall of civilizations" (10).

It appears that only about a fifth of the world's soils have actually been surveyed. The highest percentage of survey coverage is found in Europe, and the lowest in Africa. When percentages are calculated after deduction of arid regions and permafrost areas, which are surveyed only in a few instances, Class I surveys cover respectively 10.8, 23.3, 15.4, 80.2, 46.1, 15.0 percent of the regions listed in Table 2 and 28.2 percent of the world (9).

Table 2 - Soil Survey Coverage (percent)

	Class I	Class II	Class III
Africa	7.5	38.0	54.5
Asia	19.0	49.0	32.0
Australasia	11.0	61.0	28.0
Europe	76.3	23.7	-
North & Central America	28.0	16.0	56.0
South America	14.6	45.9	39.5
World	21.0	40.0	39.0

With remote sensing and satellite imagery techniques supported by ground truth studies, it should be possible to intensify soil survey work. Without soil suvey data, scientific land use planning based on land capability estimates becomes difficult.

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(b) Flora and Fauna - Living organisms are remarkable for their diversity. Our earth to-day supports an estimated number of between 5 to 10 million species of plants and animals. This enormous variety of living organisms has been generated by three billion years of evolution, through a process that has involved continual creation of new species and extinction of old ones. Till recent times the creation of new species has kept pace with the extinction of old ones, so that the total number of species had been slowly increasing. Beginning with pleistocene, ten thousand years ago however man has been responsible for a stepping up of the rates of extinction so that the overall number of species has since been on the decline.

The problem of ecological damage has assumed such serious proportions that the World Conservation Strategy proposed by the International Union for Conservation of Nature and Natural Resources with the assistance of the United Nations Environment Programme and the World Wild Life Fund in 1979, ought not to be delayed in its implementation any longer. According to the calculations of IUCN, some 25,000 plant species and more than 1000 species and sub-species of mammals, birds, amphibians, reptiles and fish are threatened with extinction. These figures do not take into account the inevitable losses of small animal species, particularly of invertebrates like molluses, insects and corals whose habitats are being eliminated in their entirety. Estimates that take into account the small animal species suggest that half a million to a million species will have been made extinct by the end of this century (11). Because of the destruction of habitats, even an animal like the elephant is now included in the endangered category. Unfortunatly the process of gene erosion and species extinction is proceeding without abatement although there is at least an awareness now of the danger to human existence that this continuing loss symbolises. Naturalists view the situation with an air of sorrow and despair. For example in a recent book entitled "Stones of Silence", George B. Schaller writes as follows:

> "At most a few hundred Kashmir stags, a sub-species of red deer, survive in the Vale of Kashmir, their only home. Yet as recently as 1947 there were over 4,000, the animals having brought to the verge of extinction because no one cared. There are many species similarly threatened, all in need of some one concerned enough to fight for their needs. The fact that a living being can vanish from the earth solely because of man's improvidence and neglect is appalling and the utter finality of it touches the consciousness of far too few. I have met in the Himalayas many species without a future."

What we need urgently is a global "Economic Ecology" movement which will help to preserve for posterity the fruits of millions of years of evolution and natural selection. Such a movement should aim at establishing a global grid of Biosphere Reserves, Gene Sanctuaries, National Parks and Hot Spot locations for screening for resistance against pathogens.

(c) Environment - The participants at a recent international seminar held in Vienna came to the following conclusions about the carbon dioxide problem:

> Carbon dioxide is increasing in the atmosphere and may cause 'green house' effect on the earth. Most of the increase in CO_2 concentration is due to the burning of fossil fuels, but partly it could be due to deforestation. There could be an increase of 2-3°C temperature of the globe with the doubling of CO_2 concentration, which could influence agriculture,

fisheries and other biota. It is difficult to specify the regions which would be affected most but some effects could be in tropical regions also. One of the measures to control this situation is to change the use of sources of energy. For example, a change to renewable biomass may be more beneficial.

(d) Population growth: Compounding all these difficulties, the problem of population stabilisation is still eluding any simple solution. It is, however, clear that population stabilisation programmes succeed only when measures designed to promote them are conceived and introduced as an integrated package with concurrent attention to education, health care, maternal and child nutrition and environmental sanitation.

Experience in Ghana suggests several encouraging approaches to this problem. In the early seventies, the Ghanaian Government attempted to bring clinic services to rural populations by organizing mobile family planning teams in the Danfa region north of Accra. These clinics travelled from village to village providing birth control services. Their work was supplemented by the staff of maternal-child health centres and by village-based primary health care workers.

Although the project started out as a traditional, female-oriented program, it soon became more of a male effort when nearly half the clients were men. In the male-dominated society of Danfa, men turned out to be much more conscientious birth control users than women. They also proved to be better family planning advocates. More men than women tried to persuade their friends to use contraception. And men who chose a birth control method either for themselves or for their partners reported that their partners had fewer pregnancies than the women who participated directly in the program.

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Before the project, women in Danfa had an average of eight children. Now contraceptive use in the region has increased and fertility is falling in some areas. An evaluation of the program by the School of Public Health at the University of California at Los Angeles suggests that at least one-half the fertility reduction in Danfa is related to male acceptance of birth control.

The success of the Danfa program indicates that men like women, seem to want smaller families when it is clear this will improve their opportunities for a better life for themselves and their families. When the men of Danfa were asked to explain for themselves why they chose to practice contraception, their responses showed a remarkably unselfish concern. The most common reason given was the improvement and preservation of the health of their children. Men were also concerned with protecting their wives' health and with making it easier to educate their existing children (12). Population stabilisation programmes should have a symmtrical approach with equal attention to men and women.

The economic emancipation of women is another important requirement for promoting the voluntary adoption of the small family norm. In many developing countries, women not only work in the field for producing food but also in the transformation of food into something that can be eaten. In Africa, these tasks represent 40% of the work necessary to feed the family. The work includes - digging, ploughing, sowing, planting, hoeing, weeding and plant protection. Women help plant harvest and transport the produce from the fields to the village. In forest areas, women grow root vegetables and condiments. In Savanna areas, they help to grow millet, frequently in their own vegetable plots. In nomadic systems of living, women in addition to domestic tasks, devote themselves to the care and maintenance of livestock. Women are quite

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frequently affected by changes in traditional land use systems. Thus, according to Bukh (13), with the introduction of cocoa in Ghana, men stopped producing yams since they had to be harvested at the same time as the cocoa. Thus women were forced to cultivate the food crops and they replaced yams with cassava since the latter required less labour and yielded more per hour of work. This arrangement, although was beneficial from the point of view of output, resulted in a drop in the quality of the diet, since yam has a superior nutritive value as compared to cassava. There are also problems in several developing countries of Asia and Latin America, arising from women's rights having been completely overlooked in agrarian reform programmes. There is hence need for making a specific assessment of the impact of developmental and social measures on the welfare of women.

Agricultural Balance-Sheet - Having considered some of the major agricultural assets as well as liabilities; the question now arises as to what can and ought to be done to maintain the agricultural balance-sheet in such a manner that production and productivity can be enhanced in all major terrestrial and aquatic farming systems without detriment to the longterm production pontential of land and water. Agriculture is an occupation where no depreciation can be allowed in its basic assets like soil and water. The management of the agricultural balance-sheet is hence a much more sophisticated and difficult task than the management of the financial balance-sheet of governments. The reason is obvious. "Ecological economics" has an important added dimension, namely, a time horizon extending to infinity. Conventional economics may deal with problems in the span of the life time of one generation or even a few generations, but ecological economics has to look at problems till the

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end of the human race. Quite frequently this aspect is ignored while calculating cost-benefit ratios and while making investment decisions in different sectors of the economy.

In spite of the problems and pitfalls I have so far referred to, the untapped production reservoir in the world as a whole and in Africa in particular with regard to the absolute maximum food production potential is very high. The calculations by Buringh, van Heemst and Staring, for example, indicate that the absolute maximum production potential in terms of a grain equivalent is about 10,845 tonnes per year (Table 3). This constitutes 21.8 percent of the global food production potential (14).

Table 3 - The absolute maximum production of grain equivalents (total and per hectare) of the continents and the world.

	MPGE (10^9 ton)	% MPGE	Average MPGE ($kg.ha^{-1}.year^{-1}$)
S. America	11106	22.3	18014
Australia	2358	4.7	10447
Africa	10845	21.8	14259
Asia	14281	28.6	13182
N.America	7072	14.2	11250
Europe	4168	8.4	10454
Total world	49830	100.0	13368

MPGE : Màximum production of grain equivalents.

For the purpose of this calculation, Africa has been divided into 33 broad soil regions. 23.5% of the land area in Africa is potentially agricultural land. After South America, this continent has the best possibilities for increasing food production. In fact 73% of the total potential in terms of grain production occurs in the developing countries of Asia, South America and Africa. These are also the centres of origin of most of the

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important crop plants and farm animals of the world. It is, ironical that the ancient centres of origin of crop plants should to-day be characterised by low productivity and widespread poverty. We should ask ourselves as to why crop plants are unhappy in their historic homes?

Before I deal with the steps essential for taking to a pathway of accelerated economic advance without destruction of ecological assets, I would like to refer to the two major contrasting agricultural management systems now co-existing in the world.

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IV. PATHWAYS OF AGRICULTURAL DEVELOPMENT : SUPER FARMS AND SMALL FARMS.

The world to-day is witnessing two contrasting trends of evolution of farm management systems. In one system occurring in free-enterprise countries like the United States, Canada and Australia as well as in socialist countries like the USSR, eastern Europe and China, the size of an operational holding is getting larger and larger. In the other system found in many of the developing countries of Asia and Africa, the size of a farm holding is tending to get smaller and smaller. We can thus recognise, on the one hand, large super farms based on capital and energy intensive and labour displacing technology, and on the other, very small farms operated largely with family labour and with very little capital or energy investment.

Super Farms

Among super farms, three different broad categories can be recognised:

(a) U.S. Model - The United States to-day serves as a major bread basket of the world. A good example of the trend in U.S. farming methodology is provided by the rice culture operations in California (15):

> "The production of rice in California has evolved into one of the most highly mechanized agricultural operations in the world, including the levelling of fields by laser beam, the sowing of seed by air-plane and the harvesting of the crop by special combines that do not bog down in the mud of the rice paddy. The 1979 California yield of 6,450 pounds of rice per acre was 50 percent higher than the average in the other rice-producing states in the U.S. and nearly three times higher than the world average of 2,360 pounds per acre. Although the acreage devoted to rice in the U.S. is only 0.9 percent of the world total, the U.S. produces 1.7 percent of the world crop and in many years is the world's largest rice exporter."

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It is widely recognised now that super farm management technology of this kind is based on a heavy consumption of non-renewable forms of energy. In this system, energy consumption is high not only in the production phase but also in the post-harvest phase of the production-consumption chain. Serious thought is hence being given now to methods of reducing the high dependence on fossil fuels in achieving productivity improvement. For example, a study conducted on agricultural production efficiency by a Committee of the U.S. National Academy of Sciences showed that modern cropping systems in the United States yielded less than 5 calories of digestible energy per total calorie of agricultural energy. Out of various systems studied, the most energy efficient agricultural systems were labour intensive vegetable growing in New Guinea and rice culture in the Philippines (16). However, these comparatively efficient cropping systems were also the least productive in terms of digestible energy per hectare. Inother words, the pathway of productivity improvement chosen in the super farm management system involves an exponential rise in energy consumption.

(b) Soviet Model - The Soviet model of super farm operations largely consists of big State/collective farms. Since the land is socially owned, a collective farm is run like any other State enterprise. The farms are highly mechanised and because of weather conditions in the USSR, energy consumption in these farms also tends to be very high. Many developing countries have also experimented with such large mechanised farming methods. We have in India a few large State Farms started with the help of USSR. These are mostly used now for seed production. In Ghana also there have been a few large State farming enterprises supported with appropriate machinery. However production from such enterprises constitutes only a small proportion of total production. The small holder sector is still responsible for over 95% of domestic production in Ghana.

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(c) Co-operative agro-industrial complexes: The third kind of super farm model is the one found in several Socialist countries in Eastern Europe. This involves the organisation of a large contiguous area into an agro-industrial complex. Each agro-industrial complex has a land use model based upon both ecological and economic considerations. Production, processing and marketing are linked together into an integrated system. The Complex provides the needed facilities to the farming families who are all members of the co-operative which manages the complex. Land is not individually owned but the members of the complex have a sense of belonging because of the institutional devices introduced for promoting a sense of participation in the management of farm operations - other socialist countries like China have also introduced co-operative systems of management of farm operations within a framework of social ownership of land.

Thus the super farm kind of organisation of agriculture is assuming different manifestations based upon the land ownership pattern, i.e. private versus State ownership. Whatever the administrative or ownership structure may be, the super farm operation provides opportunities for introducing scientific management systems such as the following:

1. Crop planning in accordance with agro-meteorological and soil-moisture-retention data;

2. Minimum or appropriate tillage suited for multiple-cropping and intercropping systems;

3. High plant density leading to dense crop canopies;

4. Weed-free environment;

5. Controlled release of fertiliser, use of nitrification inhibitors, foliar feeding and use of low cost, anhydrous ammonia;

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6. Use of bacterial, algal and other microbial fertilisers;

7. Integrated nutrient supply involving an appropriate blend of organic, inorganic and biological sources of fertiliser;

8. Better on-farm management of water, including drip irrigation in arid land;

9. CO_2 fertilisation for maximising production in glass-houses;

10. Integrated pest and disease management involving crop sanitation and agronomic, genetic, biological and chemical methods of control;

11. Use of hormones and growth regulators in fruit trees and ripeners in sugarcane;

12. Organic recycling leading to crop-livestock, cropfish, and crop-livestock-fish integration.

The super farm technology can also generate the necessary resources to overcome problems arising risk and return and can help in efficient marketing. However, this kind of farming also faces a few major problems:

(a) high consumption of non-renewable form of energy;

(b) environmental pollution arising from the application of large doses of chemical fertilizers and pesticides; and

(c) problems of motivation under conditions where the indvidual has no long term stake in the land and works like any other Government employee.

Confidence has been expressed by several experts that the energy-intensive super-farm technology could be reoriented gradually towards a zero-energy farming system. For example, Leach (17) describes what can be done in North Amercia and Western Europe as below:

"The energy-intensive Western farmer could, with little trouble, reduce his overall energy consumption

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dramatically -- and without any loss of yields or return to labour-intensive methods. Recycling animal wastes partially to replace artificial fertilizers, or using them to generate methane, are two frequently urged solutions since they solve the sometimes critical waste disposal problems too. But by far the largest impact would be made by using sensibly a natural fuel that many farmers now burn wastefully and destructively in their fields -- cereal straws.

Most farms grow cereals. An average acre of cereals in the U.K. yields roughly one ton of straw with a gross energy value of 3 million kcal (2000 kcal/lb, 30% moisture content in the field). This is roughly equal to the total energy input per acre for most farms, and is more than twice the energy used per acre as fuel and electricity for all farms except pig and poultry enterprises. Preliminary work at Nottingham University (Wilton) shows how this straw might be harvested and turned into a fuel for a very low energy cost. The entire cereal plant is cut with a forage harvester (instead of a combine for the grain plus a tractor and cutter-baler for the straw) and dried. After drying, the grain and straw are separated, and the straw could be burned either in a furnace to provide heat for drying, or in an external combustion engine (e.g. Stirling cycle) to provide mechanical power or even electricity. The straw drying would consume about 12 to 15 gallons of fuel (600,000 to 700,000 kcal) under average conditions, giving a net energy yield of 2.3 to 2.4 million kcal. Alternatively, the straw could be fermented (without drying) to a liquid fuel such as alcohol with a net energy yield of around 1.5 million kcal/

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acre plus by-product material for feeding ruminants. This last figure, equivalent to 36 gallons of diesel fuel, is higher than the liquid fuel consumed/acre for all farms except pig and poultry, and is over 50% higher than the consumption for dairy and cereal farms. With a judicious mixture of fermentation and direct straw-burning, including burning to generate power, and with animal wastes providing methane or nitorogen, phosphorus and potassium, it seems entirely probable that many farms might become self-reliant for all fuels and power, and would need to import energy only in the form of some fertilizers, machinery and other technical equipment, and sprays."

Phosphorus management and recycling becomes particularly important since phosphorus sources are non-renewable.

The super-farm free-enterprise technology is not without its own socio-politiĉal problems.

Wolf (18) studied six major instances of "Peasant Wars of the Twentieth Century". He concluded:

"Thus paradoxically, the very spread of the .... market principle also forced men to seek défences against it. They could meet this end either by cleaving to their traditional institutions, increasingly subverted by the forces which they were trying to neutralize; or they could commit themselves to the search for new social forms which would grant them shelter. In a sense all our six cases can be seen as the outcome of such defensive reactions, coupled with a search for a new and more humane social order."

A more recent study on the causes which led to farmers' protest in the State of Kansas in the United States also indicates that uncertain farm prices in a time of inflating farm costs is tending to get farming resources concentrated into fewer hands and thereby lead to a decline of the rural economy and society. This study also showed that while farmers of Kansas State were ideologically committed to "the free market concept", they favoured such non-market solutions as target prices, favourable loan rates, production controls and collective bargaining (19). The primary need of the system was identified as an yearly orderly marketing programme. In the free enterprise super farm production systems, there is, therefore, a re-appraisal of both energy consumption pattern and the public policy support essential for protecting farmers' interests.

Under the large mechanised farming operations, the profit per farmer will obviously be high. For example, according to USDA, one American farmer feeds 56 people and by this yardstick the American farmer can be stated to be the most productive. But when we measure productivity in terms of land or capital or energy, this superiority is no longer true. This is where small farms have both an advantage and an opportunity. Small farm development is also taking place in different directions. More than 90% of all tropical farms are less than 5 hectares in size. National averages in Asia are often less than 3 hectares. Because of erosion and top soil loss, the nutrient status of many soils in the tropics and sub-tropics is not favourable for high productivity. The highly skewed rainfall pattern makes the land not only hungry but also thirsty during large parts of the year. Thus low soil fertility, poor soil structure, poor seed, uncertain water availability, extreme temperatures, lack of access to inputs and markets, all reduce the productivity of small farms in the tropics and sub-tropics. However, under conditions where land is limiting, very highly productive and energy efficient systems of farming have been developed during

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the last 20-30 years. Japan, Taiwan and North and South Korea have all reached high levels of productivity in crops like rice under small farm conditions. China has also reached an average yield level in rice of over 3 tonnes per hectare in an area exceeding 30 million hectares. Although land is socially owned in China, the density of farming population is high. Systems of co-operative management particularly of irrigation have helped in ensuring a high average yield. Data collected from selected villages in Asia show that there was no significant difference in the average yield of rice per hectare between large and small farmers adopting modern varieties except in Indonesia. These data are consistent with the hypothesis of scale neutrality of new technology. Vernon Ruttan (20) after a review of the available micro-level data in Asia concluded "neither farm size nor tenure has been a serious constraint to the adoption of new high yielding varieties" and "neither farm size nor tenure has been an important source of differential growth in productivity."

Harwood (21) has, in a recent book on 'Small Farm Development', dealt with the various factors which are involved in improving the productivity of small holdings. For launching productivity improvement under small holders' conditions, there is need for developing institutional structures which can promote collective or group management of certain farm operations like water management, plant protection and post-harvest technology, without affecting the individuality of ownership. If this does not happen, there will always be co-existence of certain unique farmers who produce very high yields while at the same time the average productivity of the area is very low. In other words, the challenge lies in making the unique into universal. In my view, several steps are essential for assisting small farmers to overcome their handicaps in the following fields and thereby maximise productivity:

a) The farmer has adequate food of acceptable quality for his own family;

b) He has confidence in his own technical, agricultural and commercial skills;

c) His farming system is ready to respond to additional inputs;

d) He has the technology to turn inputs into increased production;

e) He has access to markets and to the cash economy.

Some of the major steps involved in deriving full production and economic benefit from small operations are described below:

1. Organisation of Land Use Boards - In order to help in re-structuring land use patterns on scientific lines, it would be desirable to organise Land Use Boards with high-level inter-disciplinary expertise. Each Board can cover a specific agro-ecological area. Such Land Use Boards should assist farmers in optimising the economic benefits from land and water through attention to the following major ingredients of scientific land use:

a) Ecology - Land use based on ecological considerations will help to maximise the economic benefits from a given environment and minimise damage through man-made as well as natural processes of desertification. Agro-meteorological research data will have to be integrated in crop planning models, so that contingency plans suited to different weather probabilities can be prepared. Also, an action - reaction analysis will have to be done in irrigation projects not only to avoied salinization and water logging but also the spread of new vector borne diseases.

b) Economics - For re-orienting land and water use on the basis of sound principles of economics, it is essential that production, storage, processing and marketing are viewed as a total system. The prevailing

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mismatch in many farming systems between these two areas of the production-consumption chain is harming both producers and consumers. For bridging the gap between potential and actual farm yields, it will be necessary to identify the precise constraints operating in each area and remove them. When post-harvest technology is neglected, opportunities for the preparation of value-added products are lost. For example, food production statistics simply state that during 1978-79 India produced about 131 million tonnes of foodgrains. This ignores the fact that the plants represented in this statistics produced over 400 million tonnes of dry matter, out of which grains constituted about 131 million tonnes. If the entire biomass is viewed as an asset and is utilised effectively, new avenues of income generation can be opened up. A part of it is currently used for feeding animals or as fuel. But by looking at the dry matter yield part by part and by introducing techniques of preparing value-added material, rural incomes can be enhanced.

c) Energy - The energy needs of agriculture will have to be carefully worked out and an integrated energy supply system involving a suitable blend of renewable and non-renewable forms of energy will have to be introduced in each agro-ecological area. So far the pathway of productivity improvement has tended to rely heavily on a growing consumption of non-renewable forms of energy. We will have to reverse this process through the promotion of organic re-cycling techniques and through the wide-spread use of biological sources of fertilizer like azolla, blue green algae and symbiotic and non-symbiotic forms of nitrogen fixing organisms. Also the current tendency to cultivate energy-rich crops like grain legumes and oil-seeds under conditions of energy deprivation has to be corrected. Phosphorous conservation and re-cycling

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will be particularly important since phosphorous is a non-renewable resource. These steps will be facilitated if the farmers in each area organise "Renewable Energy Associations" and adopt a scientific energy conservation, generation and utilization methodology.

d) Employment - Famines in India have been described as "famines of work than of food, since when work can be had and paid for, food is always forthcoming". The situation today in the field of nutrition is one of providing the wherewithal to purchase food rather than just the availability of food in the market. All estimates of employment potential show that a majority of the people in India will have to depend upon agriculture, agro-industries and small-scale industries as the major source of income until the end of this century.

Thus the Land Use Boards will have to develope a package of incentives and disincentives which can help to achieve the objectives of increasing income, employment and food production from the land, water and sunlight resources available in each district.

Such a Board should have on it a nutrition scientist who could help in suggesting suitable crops which would help to meet the following needs:-

a) Preparation of home-made weaning foods;

b) Providing some critical missing nutrients in the diet, like Vitamin A, Vitamin C, iron, etc.;

c) Developing a cereal-grain-legume combination so that all the essential amino acids can be provided in the diet;

d) Introducing appropriate fodder legumes and shrubs which could provide the needed calories and proteins to farm animals, thereby enabling the introduction of larger quantities of animal food, like milk and milk products, eggs, etc., in the diet;

e) Developing suitable agriculture-cum-aquaculture techniques which could help in promoting dietary combinations, like rice-fish, potato-fish, etc.; and

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f) Promoting agro-forestry systems of land management where appropriate botanical remedies to the specific nutritional maladies of the region get incorporated.

A majority of the farmers in countries in S.E.Asia have less than one hectare of land to cultivate. They have to meet their own food requirements and in addition, should have some surplus produce for sale. An important method of obtaining supplementary income in such cases is the integration of animals in the farming system. It is necessary that suitable technologies are developed for preparing fortified feed material from all cellulosic wastes and from agricultural raw material. Fortification of straw with molasses and urea as well as microbiological enrichment of starchy material, like cassava, will have to receive much wider adoption.

The other area of relevance in terms of agricultural programmes is the addition of nutritional considerations in social forestry projects. Suitable trees which can provide fruits, nuts and foliage of interest from the nutrition view-point will have to be introduced in programmes, such as "A Tree for Every Child", village forestry, etc. There is a vast untapped potential in this field.

2. Rural development - Rural development in the ultimate analysis involves the provision of opportunities for the optimum utilisation of the human resource in rural areas. Human resource development in its turn can take place only on the foundation of adequate nutrition and work opportunities. It is, therefore, necessary to base rural development programmes on the primary aim of providing opportunities for the human population to achieve optimum expression for their physical and mental potential. Such programmes should have the following four major components:-

a) Economic amancipation of the family with particular attention to provision of adequate employment opprotunities to women who are largely engaged at present in unpaid and underpaid jobs, often characterised by physical drudgery;

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b) Education of Children and adults;

c) Provision of minimum needs, such as safe drinking water supply, health care, rural communication, etc.; and

d) Promotion of a small family norm through population and contraceptic education.

Experience with programmes such as "Food for Work" Programme of the Government of India and "Employment Guarantee Scheme" of the State Government of Maharashtra in India have provided useful insights into methodologies for nutrition improvement and rural infrastructure development. For example, the Employment Guarantee Scheme of Maharashtra has revealed that there was predominance of females in 52 out of 87 selected works. The female participation was on an average 57% in many rural works programmes. A similar observation has been made in several areas where the "Food for Work" Programme has been in progress. The fact that women will have additional income and in the case of "Food for Work" Programme, will also receive directly foodgrains has an important implication from the point of view of nutrition of children. Thus, carefully designed rural development programmes which can generate diversified opportunities for employment and help to provide adequate nutrition will hasten agricultural advance.

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3. Systems Approach to Research & Development - Mixed farming involving crop-livestock integration and mixed cropping involving the simutaneous cultivation of two or more crops in a field and multiple cropping leading to taking 2-4 crops per year in the same plot of land are all characteristics of tropical and sub-tropical farming. In the past, both research and developmental efforts were organised more on the basis of individual crops or farm animals. We now know that what the farmer needs is advice and assistance relevant to the entire farming system around which the lives of the farmer and his family revolve. Fortunately an awareness of this need is now growing. Some of the major farming systems which require attention in this respect are the following:-

(a) Multiple-cropping systems in irrigated areas

various two-, three- and even four-crop sequences are now being followed. In promoting multiple-cropping systems, attention should be paid to ensuring that grain and fodder legumes find a place in the rotation. Also, crops having the same pests and diseases should not be grown in succession. Introduction of grain and fodder legumes in the rotation will improve human nutrition as well as soil fertility. A mung bean-rice-wheat rotation is a good method of combining cereals and legumes in north-west India. Short-duration varieties of pigeonpea (Cajanus cajan) have made pigeonpea-wheat rotation possible. A jute-rice-wheat rotation is becoming popular in parts of Assam and West Bengal in India as well as in Bangladesh.

The introduction of relative insensitivity to photoperiod and temperature through breeding has been responsible for the development of 'period fixed' rather than 'season bound' varieties. For purposes of breeding varieties for multiple-cropping, per-day yield has to be used as a selection criterion in segregating generations. Also, other factors such as seed dormancy will need attention, since if a crop ripens before the monsoon rains have ceased, the grain will sprout if there is rainfall at harvest time.

(b) Rain fed farming

Production possibilities in high-rainfall areas are similar to those in irrigated areas. However, in the un-irrigated semi-arid areas commonly referred to as dry-farming areas, considerable production risks exist. Grain legumes, sorghum, millets and oilseed crops are mostly grown in such areas. A wide variety of fruit trees can also be grown. Research thrusts in semi-arid areas should lay stress on water and soil conservation and land-use planning based on precipitation, evapotranspiration and the moisture holding capacity of the soil. Contingency plans should be developed and introduced so as to minimise the risk of total crop loss during aberrant weather. It is also necessary to find more profitable crops for some of the semi-arid areas. There are many under-exploited plants with potential economic value.

Plant breeders should develop varieties which can be grown in flood-free seasons in chronically flood-prone areas and drought-escaping varieties in drought-prone areas. For this purpose, there has to be collaboration between plant breeders and agro-meteorologists.

(c) Mixed cropping and intercropping

Various crop combinations are used by farmers, particularly in unirrigated areas, but not all are scientifically sound. Therefore, intercropping systems based on complementarity between the companion crops have to be developed. Among the major components of complementarity are: (i) efficient interception of sunlight; (ii) ability to tap nutrients and moisture from different depths of the soil; (iii) non-overlapping susceptibility to pests and diseases; (iv) introduction of legumes to promote biological N fixation and increase protein availability.

(d) Multi-level or three dimensional cropping

In garden lands where a wide variety of plantation crops, fruit palms and other tree crops are grown, it is possible to design a crop canopy in which the vertical space is utilised more efficiently. Plant architects will have to take into account the effective use of both horizontal and vertical spaces when breeding varieties for use in three-dimensional crop canopies. Efficiency in such a cropping system will again be based on the extent of the complementarity generated among crops in the system. For example, studies in India have shown that coconut, cocoa and pineapple form a good combination which intercepts sunlight efficiently in a combined canopy and also extracts nutrients and moisture from different depths in the soil profile. Studies on the root system of companion crops are of particular importance. The introduction of grain and fodder legumes in these 3-dimensional crop canopies will provide opportunities for animal husbandry. A careful study of all the major garden land cropping systems based on the extent of symbiosis and synergy among the system components will be useful in developing specifications for plant breeders to use in developing ideotypes (i.e. conceptual plant types) for efficient performance in 3-dimensional crop canopies.

(e) Kitchen gardening and home fish gardening

Kitchen gardening can be one of the most efficient systems of farming from the point of view of solar and

and cultural energy conversion. Vegetables rich in beta carotene and iron need to be developed and popularised. If planned intelligently and scientifically, backyard gardens, roof gardens and other methods of growing vegetables and fruits in whatever space is available around mud huts as well as brick houses can make a substantial contribution to improved nutrition. Where ponds are available in large numbers, home fish gardening can be an excellent method of supplementing food and income.

(f) Forestry and agro-forestry

The importance of improving the productivity of forest canopies cannot be over-emphasised. Agro-forestry has been defined as a sustainable management system for land which increases overall production, combines agricultural crops, tree crops, forest plants and/or animals simultaneously or sequentially. Sylvi-pastoral, sylvi-horticulture, sylvi-agriculture and other combined land-use systems are extremely important for the food, feed, fuel and fertiliser needs of people in many hilly regions. Plant breeders have yet to give attention to breeding varieties suitable for such systems of sylvi-culture. Shrubs and trees suitable for raising energy plantations in villages and initiating "gasoline agriculture" need to be identified and improved.

(g) Mixed farming

Mixed farming systems may involve (i) crop-livestock, (ii) crop-fish, and (iii) crop-livestock-fish production programmes. In South East Asia, fishing in rice fields is common. The minimal use of pesticides will be important in order not to create problems of fish mortality and transfer of toxic residues through the food chain. This will involve maximum use of genetic resistance and the development of integrated pest-management systems.

(h) Sea farming

There are considerable opportunities for the spread of scientific sea farming practices involving an appropriate blend of capture and culture fisheries. The rate of growth of oysters, mussels, prawns, lobsters, eels and a wide variety of marine plants and animals is high in tropical seas. If along with such integrated sea farming practices, the cultivation of suitable economic trees like casuarina, cashewnut and coconut can be popularised along the coast, thriving coastal agriculture-cum-mariculture systems can be developed. In addition to improving income and nutrition, such farming systems can help arrest coastal erosion.

4. Constraints analysis and removal - Agriculture starts moving forward only when an appropriate package of technology is supported by suitable packages of services and public policies which can help all farmers irrespective of the size of their holding and their innate input mobilising and risk taking capacity to take to new technology. For identifying the precise constraints which are responsible for the prevailing gap between potential and actual farm yields, it is necessary to conduct an inter-disciplinary constraints analysis of the kind shown in Fig. 3. To be meaningful, such an analysis will have to be done in compact areas with similar farming systems and socio-cultural factors.

As I mentioned earlier, an important constraint under conditions of small holdings with individual land ownership is the difficulty in achieving a high level of farm management efficiency. For example, if two neighbouring farmers adopt totally divergent approaches in the field of pest control, the farmer who wishes to achieve high levels of production may have to resort to a larger number of sprays of pesticides than would otherwise have been necessary. Hence a challenge to development planners and administrators dealing with small farm conditions lies in introducing suitable package of services which can help to introduce an area approach in management wherever this is necessary.

For optimum efficiency, a blend of cash and non-cash inputs will be necessary. Such services are best provided by farmers' own organisations supported by appropriate training, credit and marketing assistance from Government. The organisation of community nurseries in crops like rice where transplanting is done, the introduction of rotational distribution of water in the command areas of irrigation projects so that all farmers in the command get equal quantities of water and the supply of credit and the needed inputs before the sowing season in properly organised credit-cum-input supply village fairs are examples of the approaches which have been found useful in India.

5. Labour utilisation in relation to irrigation and cropping intensity - The greatest challenge under small farm conditions is effective labour utilisation. With increasing world population, it is imperative that the basic needs of the increasingly growing number of people should be satisfied. One important basic need is productive employment, which is one of the most acute contemporary social problems of virtually all developing countries. It has been estimated that some 75 million people are currently unemployed and according to both ILO and the World Bank, some 1 billion new jobs have to be created between now and the year 2000[22]. The average annual percentage growth rate of the labour force in developing countries is estimated to rise from 1.8 during 1960-70, to 2.2 in 1970-90, and to 2.1 during 1990 to 2000[23]. This means that creation of new

employment opportunities for people entering the labour force will become more difficult in the future than in the past due to the increasingly rapid growth of the labour force. Reduction in the rate of population growth, while desirable and essential for the long-term solution, will not reduce the magnitude of the problem over the short run, since the entrants to the labour force for the next 20 years are already born. Furthermore, there has been an increase in absolute number of workers in the agricultural sector of nearly all developing countries, which raises serious questions on the validity of the assumption that industrialisation will reduce total unemployment. Even in countries like the Republic of Korea, the percentage of the labour force in agriculture decreased from 70 percent to 50 percent during the period 1950 to 1970 due to the growing demand for industrial labour, but the number of agricultural workers in absolute terms still increased[23]. Consideration of both unemployment and under-employment makes the problem even more serious for most developing countries.

According to FAO[24] estimates, the magnitude of irrigation programme to be executed by 1990 in developing countries can be realised from the following statistics:

- 22 million hectares of new irrigation,
- 45 million hectares of improved irrigation,
- 78 million hectares of drainage,
- 440 thousand million m^3 of additional irrigation water,
- 97 thousand million dollars of investment at 1975 prices.

India alone has a programme for bringing about 14 million hectares of additional land under irrigation during 1980-85.

Irrigation helps to promote multiple cropping and mixed farming which are two of the most potent tools in improving employment opportunities in rural areas. However, even with all these advances, the net 'take-home' income of small farmers remains low. Therefore, peasant revolts have now begun under conditions of small holdings not only because of unjust agrarian relationships but also because of marketing difficulties. When agriculture advances, more and more farmers will have products to offer to the market, after satisfying their home needs. However, in quantitative terms, the produce which a small farmer is able to market will be small. Therefore, his net income also remains small. The average size of a farm family in many low income developing countries exceeds 5 and in the villages a large number of landless labour families also live. Arising from such a situation, the demand for a high price for agricultural produce is frequently made. Sometimes affluent nations like Japan have resorted to very high price incentives to induce small farmers to increase their productivity. Assured and remunerative marketing certainly provide the greatest stimulus to farmers since farming is a highly risky profession particularly when there is no assured irrigation. Very high levels of price designed to increase the total 'take home' income of small farmers will, however, become counter-productive under conditions where the average consumption levels of the population is already low and under- and mal-nutrition are widely prevalent. The situation is different in countries like Japan which can afford a large subsidy programme because of very high industrialisation. This is a new dilemma in which many countries with predominantly small holdings now find themselves in. Here again each country will have to develop public policies which can simultaneously promote production and consumption.

The two key requirements in this respect are: first, organisation of small farmers both for improving farm management efficiency through concurrent attention to monetary and non-monetary inputs and for ensuring that the producer gets a high proportion of the price paid by the consumer; secondly, a well-planned programme of diversification of employment and income generation opportunities in rural areas so that a part of the farm labour can get absorbed in the secondary and tertiary sectors. This will call for a more detailed planning of the scientific utilisation of local resources, so that value-added products can be prepared from all agricultural raw material and suitable small and village industries promoted. Government policies should enable the location of appropriate industries in the rural areas and an employment impact analysis should be introduced in all development projects.

Given the above steps, I am confident that the small farm technology can, on the one hand, acquire the strengths of the super farm methodlogy and at the same time avoid the difficulties in terms of ecological and energy costs which the super farm procedures involve. Making small farmers acquire the strengths of super farm cultivations, while avoiding their weaknesses is thus a major challenge to agricultural technologists and planners working in developing countries.

V. BUILDING A DYNAMIC AGRICULTURAL SYSTEM

A dynamic agricultural system capable of responding to the needs of today as well as tomorrow can be built only under conditions where the development strategy is in harmony with the socio-cultural and socio-economic conditions as well as the agro-ecological features prevailing in different parts of a country. A great agricultural asset of most of the developing countries in the tropics and sub-tropics is the existence of a large untapped production reservoir even at current levels of technology. For Africa as a whole, the potential agricultural area has been estimated to be about 23% of the total land area. At present only 6% of the potential area is cultivated. Similarly, the average yield of about 1000 kgs. per hectare now reached in several parts of Africa is only 10% of the potential yield of 10,000 kgs. per hectare. How can this potential be tapped in a manner that does not do damage to the long-term production potential of land and water? I am raising this question because sometimes to achieve short term goals, soil fertility is mined in the same way as mining for minerals. In my view, for achieving sustained agricultural advance, there is need to pay concurrent and integrated attention to the following three major areas of action:-

(a) Development of an economically viable and ecologically sound technological package which can help to bring about a continuous improvement in the productivity of terrestrial and aquatic farming systems;

(b) Development and introduction of a package of services which can help all farmers and fishermen to derive economic advantage from new technology irrespective of the size of their holdings, their innate input mobilising potential and risk taking capacity; and

(c) Introduction of a package of public policies which can help to stimulate and sustain both production and consumption.

Agriculture starts moving forward only when appropriate packages of technology, services and public policies are introduced in a symbiotic manner. I would like to refer briefly to the major ingredients which will have to go into the making of these packages:

(a) Package of Technology: A dynamic agricultural research, education and extension system is a must for promoting a dynamic agricultural development programme. Too often, developing countries have launched ambitious production programmes without appropriate research and training infrastructure. Invariably in such projects, success tends to be short-lived. Cynical comments usually follow such disappointing exercises in agricultural development. Agriculture is basically a location-specific phenomenon. Therefore, even if suitable concepts and material can become available through international research efforts, it will not be possible to provide the kind of advice and assistance the farmers need without the support of a strong national agricultural research system. This is a point which has been repeatedly stressed by the International Federation of Agricultural Research Systems for Development (IFARD). Experience in yield improvement in countries like Japan characterised by a small size of average land holdings indicates that productivity improvement is a slow process requiring the building up of the necessary infrastructure both at the production and post-harvest phases.

In India dramatic progress has been witnessed during the last 15 years in the improvement of wheat and rice production in parts of the country like the Punjab. When high yielding and management responsive varieties of wheat carrying the Norin dwarfing genes became available in the mid-sixties, wheat production in the Punjab rose dramatically.

In India as a whole wheat production went up from about 12 million tonnes in 1964-65 to about 36 million tonnes this year. However, the production advance has been dramatic only in areas where certain pre-conditions for technology to take roots existed. For example, in the Punjab these major pre-requisites viz. owner cultivation, land consolidation and rural communication already existed when high yielding varieties of wheat and rice became available. In other words, the substrate requirements for the adoption and diffusion of technology must be fulfilled if sustained progress is to take place.

For research to be able to find solution to farmers' problems, it is obvious that the scientific programme should be organised both on an ecological and problem solving basis. Fortunately, Ghana has a good infra-structure for science, technology and higher education[(25)]. Research institutions should have both short-term and long-term goals. Whenever there is need for an immediate step up in production, the research organisation should be able to adapt and adopt suitable existing technology in an operation designed to purchase time. However, simultaneously work should be done which will help to maximise production and minimise risks. Obviously, in a country like Ghana, this would imply looking carefully at the problems and potential of each region such as the Volta Region, Eastern Region, Central Region, Western Region, Ashanti Region, Brong Ahafo Region, Northern Region and Upper Region. Those in charge of technology development should also bear in mind that a poor farmer bases his decisions not on yield per hechatre but on stable income per hectare. Hence profit maximising technology characterised by stability of income and low risk appeals to him more than just production maximising technology. This would then call for a close integration of socio-economic research with technology development.

At the same time, policy makers should understand that there will hardly be any differences between "ivory tower research" and "applied research of great value" if arrangements are not made for the transfer of technology. For example, the farmer will not be interested in a radio talk on a high yielding variety of a crop plant if seeds of that variety are not available to him. In other words, agricultural extension has to be so designed that the transfer of knowledge and the transfer of the inputs essential to apply that knowledge in the field are synchronised in time. This calls for a highly orchestrated effort on the part of scientists, extension workers and agricultural administrators in charge of input supply. Also, to farmers "seeing is believing". Hence, demonstrations in farmers' fields of new technology, both on a factor (i.e. fertiliser application, pest control, salinity reclamation, etc.) and a systems (i.e. crop-livestock, agriculture-aquaculture, agro-forestry, etc.) basis are potent instruments of extension. Care must, however, be taken to organise the demonstrations in poor farmers' fields, since the success of demonstrations in rich farmers' fields will tend to be attributed to affluence rather than to technology.

Agricultural science is now a fascinating state of development. Several old concepts based primarily on empirical observations and intuitive understanding of problems are now giving way to more science-based production systems. For example, in the field of plant breeding, individual plant performance used to be the method of choice in selection programmes in the past. Today population performance is the major index of selection. Many other criteria such as the following have been introduced:-

1. High productivity per unit of time, water, energy and air space
2. High photosynthetic ability
3. Low photo-respiration (where relevant)

4. Photoperiod- and thermo-insensitivity (where relevant)
5. High response to nutrients and other inputs of cultural energy
6. Multiple resistance to pests
7. Better nutritive and storage quality
8. Crop canopies that can retain and fix maximum CO_2
9. Suitability for incorporation in multiple and inter-cropping systems
10. Suitability for improved post-harvest technology.

Basic research in production physiology, microbiology, plant and animal nutrition and plant protection holds great promises for the future. Genetic engineering techniques may lead to the development of altogether new gene combinations. Solar energy research similarly holds great promise. It will, therefore, be prudent for developing countries to invest a certain proportion of research funds in what may be termed today "basic research" but may become path breaking research on the production front some years later.

As the pressure of population on land increases, it would be necessary to design farming systems capable of optimising the returns not only from soil and water but also from air space. In other words, 3-dimensional crop canopies involving a vertical dimension will have to be designed. More research will have to be done on root systems in relation to soil profile characteristics. Cooperative combinations of inter-cropping and mixed farming will have to be developed. The principles to be adopted in 3-dimensional crop planning are the same as already introduced in composite fish culture involving the optimum use of a cubic volume of water. Some of these possibilities are not open in temperate countries covered with snow during several months of the year. Hence such research is unlikely to be done in those countries. It is for the scientists in the tropics and sub-tropics to look at the potential offered by their own environment and help to derive full benefit from it[26].

National research systems should investigate the factors which cause instability in production. These factors can be broadly grouped into 3 categories:

(a) Weather aberrations;

(b) Pest epidemics; and

(c) Public policies.

It is possible now to mitigate to some extent the undulations caused in production by weather conditions. For undertaking relevant research programmes in this field, a strong agro-meteorological research base will be necessary. The most likely weather patterns in an area will have to be worked out on the basis of an analysis of the available information from the past. In chronically drought prone areas, the only enduring solution is the introduction of irrigation wherever possible. Even where irrigation is not available, some yield improvement can be brought about through appropriate land use and water harvesting and conservation techniques. So far there has been very little work on the development of risk minimising technology. Such technology will involve -

(a) Development of alternative cropping strategies to suit different weather probabilities;

(b) Standardisation of crop life saving techniques; and

(c) Development of compensatory production programmes in off seasons and in areas with assured irrigation.

For putting into practice these techniques, it will be necessary to build appropriate seed and fertiliser reserves. For example, if the available moisture is not sufficient to take a cereal crop, it may be possible to take an early maturing grain legume crop. This will, however, call for the building of a suitable seed reserve of the alternative crop. The investment made in such reserves will be more than compensated both by an increased production achieved under adverse conditions and by the morale uplifting impact of such technology.

Agricultural scientists should pay specific attention to maximising the return from the most limiting production factor in each agro-ecological area. Where land and not water is limiting, the strategy should aim at improving the productivity per unit of land. Conversely, where water and not land is limiting, the aim should be to maximise production from a litre of water. Similarly, the research system should look into every aspect of the production-consumption chain so that products which are produced at considerable effort are not damaged either quantitatively or qualitatively before they reach the consumer. An action-reaction analysis will also be necessary at every phase of technology development. For example, when the plant breeder releases a period-fixed photo-insensitive strain in the place of a traditional season-bound variety, problems of mycotoxicosis may arise due to high moisture content in the stored grain. Similarly, if resistance is developed in a crop variety to pathogens which thrive on a high-sugar cellular substrate, the low-sugar requiring organisms may gain in importance. Cross-breeding in animals also leads to new disease syndromes. Irrigation without an adequate understanding of soil profile characteristics can lead to problems of salinization. Water reservoirs can also become the breeding grounds of vectors of important human and animal diseases. If a nation has a capable and responsive research system, then all these problems can be faced and solved successfully. For example, a serious form of corn blight epidemic was controlled within two years in U.S.A. In contrast, many diseases like those of coconut are not even understood in developing countries.

International vs. national agricultural research - It is estimated by FAO that annual global expenditure on agricultural research is approximately US $5 billion. The investment in agricultural research by North America and Oceania accounts for more than one-third of this total. The level of funding for international agricultural research through the Consultative Group on International Agricultural Research (CGIAR) system is expected to reach about US $260 million in 1984. Among developing countries, Latin America has the highest per capita expenditure on Research and Development and has the largest number of research scientists, university graduates and students relative to the economically active population. Argentina, Brazil, Mexico and Venezuela account for over 80% of the total expenditure on Research and Development and employ over 75% of the researchers in the Region. Africa has the lowest per capita expenditure on research among developing regions. It also has the lowest number of research workers, students and graduates in relation to the population. Over 60% of the resources available for research are used in Algeria, Sudan and Egypt. South of the Sahara over 75% of the researchers are found in Ghana, Nigeria and Kenya. Developing countries of Asia as a group account for more than 60% of all research and development expenditures in developing countries. This Region has the highest expenditure in relation to GDP although the average expenditure per research scientist is still the lowest among developing countries. Over 80% of all the research personnel are found in China, India and Indonesia. The three countries spend about 90% of all Research and Development expenditures in the Region.

27. Science and Agriculture, 1980. Indian Society of Genetics and Plant Breeding, 365 Pp.

28. Mandi, P.E., 1980. Assignment Children. Published by UNICEF, 49/50, Pp. 9-16.

29. Barbara Ward, 1979. Progress for a Small Planet. W.W. Norton & Co., 305 Pp.

30. FAO, 1980. Director-General's proposals regarding Revisions of the Guidelines of International Agricultural Adjustment.

TABLE ~~B~~ A

Conservative estimate of sustainable development cost of 1 ha. of wasteland where one is lucky to have ground water e.g. in Pushkar Valley area near Pushkar Lake

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A. Land

		Cost (Rs)	Remarks
1.	Cost of land	20,000/ha.	Free given by Govt./ Panchayats/ local people. [illegible]
2.	Cost of fencing		
	a) Trench & wall	4000/ha.	Not suitable for sandy area.
	b) Bio fencing + trench and wall.	6000/ha.	Requires 3 years to stabilise and needs constant maintenance.
	c) Stone wall unmanned	20,000/ha.	Needs maintenance regularly
	d) Stone wall pacca	40,000/ha.	Too costly.
	e) ~~Stone wall~~ barbed wires with wooden poles.	20,000/ha.	Needs repairs/replacement due to termile problems.
	f) Stone wall with iron poles.	30,000/ha.	Too costly, proposed only for nurseries and to be reused after 3-4 years when bio-fencing is set up.
3.	Soil conservation and and storing raw water.	1,0000/-/ha.	Necessary for wastelands infested with sand dunes and ravines and having micro-micro watersheds (like that in the project area) contur bunding and each micro-micro watershed needs about 5 check dams/Anicuts/minidam, average cost 1,0000/-. It can cater to about 5 ha.
4.	Shelter belt	1000/ha.	To check winds : 3 tier canopy 2 sides covering system shaped belts 400 trees p/ha.

B. Water

	Cost	Remarks
1 Tubewell/ha.	1,50,000/-	
Pipe laying	10,000/-	
or 5 wells 20 meter deep in the average	10,000/-	
Running cost : Electricity (300 hrs/year)	1000/- - 3000/-	average Rs 5000 [illegible] /ha
Diesel " manual	8000/-	

Sewage water treatment and utilisation		To support well water sources during drought : Utilising pollution causing and health hazard water to support plants.
	Rs.50 lakhs	To supplement them during drought, utilisation of sewage is a must. It is also necessary to save Pushkar Lake from pollution. So sewage from Pushkar Town falling in the Pushkar Lake has been diverted by the State Government. This water is health hazard and yet precious. It must be treated and utilised.

C. Alternate sources of energy.

1/ha.	Solar cookers	Rs.600/-
	Solar drier	Rs.1500/-
	Gober gas plant/ Bio-pits. 1 for 5 ha.	Rs.2000/-

		Rs.3100/- pa/ha.

These are necessary to (a) Save trees to be cut for fuel cow dung to used as fertiliser instead of fuel.

(b) Drying products to presence them instead forced to distress sale.

D. Transport

For inputs, outputs supervision @ Rs.4/- per day appox. 250 days. 1000/- p.a./ha.

E. Labour/manpower

Atleast 1 person/ha. @ Rs.25/- per day. 9000/- p.a./ha.

F. Annual inputs, seed, fertiliser,insectiside, plants. 20,000/- p.a/ha.

ANNEXURE TABLE 'A'

Pre-revised, Per hectare costs of one time plantations in some ongoing Centrally Sponsored Schemes :

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		Cost	Trees	Remarks
1.	Rural fuelwood plantation :	Rs.5800/-/ha.	1650/ha.	Staggered to three years Rs.4000/- Rs.1000/-, Rs.800/- respectively. (The 1984-85 norms being revised to Rs.7000/- onwards).
2.	The water soil conservation in Himalayas	Rs.4800/-/ha.	1 to 2 thousand/ha.	Norms tobe revised No water problem.
3.	Area oriented fuel wood/ fodder project	6000/-/ha.	400 trees/ha. + grass.	
4.	Energy plantation	About Rs.10,000/ha.	1 to 2000/ha.	Norms to be revised.

Remarks

(a) One time plantation :

(b) No funds for semi/permanent fencing, lasting arrangement for water envisaged.

(c) No sand dune/waste land stabilisation, water problems sustaining human population contemplated.

Source : Wasteland Development Board
(1-3)

Source : PA to Director Energy Plantations
(4)

<u>TABLE 'C'</u>

Total sustainable and productive development cost/ha.

	1st year	2nd year	3rd year.
Land Fencing/soil conservation) Water storage Shelter belt	1,21,000/-	1000/-	1000/-
Water Wells	1,50,000/-	--	--
Oil	5000/-	5000/-	5000/-
Pipe laying	10,000/-	-	-
Alternate sources of energy	3100/-	-	-
Transport	1000/-	1000/-	1000/-
Manpower/Labour (one/ha. @Rs.25/- per day as the average)	9000/-	9000/-	9000/-
Other inputs Seeds, fertiliser/ insecticide/plants	20,000/-	20,000/-	20,000/-
	299000/-	36000/-	36000/-

The same order of costs is involved with development of wasteland for flower, fruit or vegitable cultivation.

TABLE 'D'

Overall cost comparison for 3000 ha.

	Sustainable, productive and lasting development (high investment - high return) (Usually by rich people and exploiting the poor)		One time plantation with meagure returns. (Ongoing Centrally Sponsored Schemes)		Indo-US (India) component of the Project Sustainable, productive, lasting, innovated plantations involving local people.	
	1st	Subsequent year.	1st year	Subsequent year	1st year	Subsequent year
Development cost/ha.	Rs.3 lakhs	Rs.36,000 per year	Rs.7000/-	Rs.2000/- per year		
Yearwise outlay	Rs.90 crores	Rs.10 crores	Rs.2.1 crores	Rs..6 crores	3·3	1·2 ·8 ·8 ·8 Crores
Total outlay for five years	Rs.130 crores		Rs.4.5 crores		Rs 6·9 Crores.	
Cost per plant.	--	--	(400 to 1500 plants average 800 plants per hectare only sturdy and thorny plants). Rs.19/-		(500 to 2000 plants average 1200 plants per ha. fruit, flower, medicinal fodder, vegitables also) Rs. 15/-	
Remarks:	No research extension or education activity.		Lack of people's involvement, no lasting assets, no research, extension, education programme, no dependable water resources, fencing, soil conservation measures taken.		Creation of lasting assets like water resources conservation measures, research, extension, education programmes, processing and marketing of products, involvement of local people and research institutions resources.	

Explanatory Note for the outlay and per hectare inputs for the Indo-US (India component).

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The task of regenerating wastelands in the semi-arid area of the Project, namely the ecologically degenerated Pushkar (Ajmer) Lake Valley System is formidable. It is infested with ravines, settlings sand and active sand dunes. It is at the marching front of the Thar Desert and faces onslaught of hot dry winds, sand storms, droughts and flash floods, silting water bodies, receeding water table, pressure of human and animal population and migrating sheep-herds. etc.

Due to successful efforts by Pushkar Project people, the local population is changing from tree cutting and digging the roots, taking up interest in plantation with great hopes.

The reclamation and regeneration activities by the Pushkar Project involve not mere plantation of some sturdy varieties or eco-degrading agricultural farming in this eco-fragile area, but consist in struggling with the initiative to develop such plant mixeswhich can provide short, medium and long term returns to local people as well as stabilise and regenerate the eco-system.

The normal cost incurred in developing water resources, taking measures for soil conservation, plantation, after care,processing and marketing the products is given in Annexure 'A'. The net cost is Rs.2,60000 to Rs. 2,80000/ha. currently. This initial cost further requires every year the inputs of the order of Rs.20,000/ha. for the most lucrative National Seed Bank Corporations norms). In return, it is expected that in five years the initial investment can be regenerated providing local people a basis to survive.

Same order of expenditure is incurred initially and every year for horticulture or flower culture.

On the other hand, the one time planting schemes e.g. of theWastelands Development Board, DNES, Social forestry are summarised in Annexure 'B'. They range from Rs.4000 per ha. for the first year,Rs.1000 for the next and Rs.800 for the third year.

They envisage about 1650 trees per ha. and assume adequate water supply and fencing etc. These norms were developed several years back and are in the process of revision to Rs.7000 to 10,000 rupees per ha. In case of fodder-cum-plant projects, with 400 plants per ha., the old norm is Rs.5600 to Rs.6000 per ha. for a block of three years. For energy plantations for about 1000 to 2000 trees per ha., it comes to about Rs.10,000 per ha. for a block of three years.

The much appreciated task force, according to its own data recently published is spending about Rs. per ha. per year.

Therefore for the sake of comparison, the 'minimum needs for sustainable development and one time plantation' the cost per year per ha. have been worked out in Annexure 'C'.

The outlay of the present project lies to the extreme lowside between the two extremes of the spectrum, i.e. the high investment-high return for actual regeneration and development of wastelands which can sustain the local people, (providing adequate self employment /returns which is Rs.2,60,000 per ha. initial and about Rs.20,000 per year as usual input, and the other, the one time plantation with meagre economic returns and no sustainable development, the costs are about 10,000 per ha. for a block of three years. (This may be split in Rs.7000 for the first year, 2000 for the second year and 1000 for the third year).

In between these two extremes, Annexures A & B, the project under submission struggles to take up nucleating inputs for an area of 3000 ha. It is looking for regenerating the existing wells, at the rate of one well for 15 ha. which is 1/10th of the normal requirement, drilling or deepening another 200 wells by a mobile drilling system, and utilising the sewage water after primary treatment. This sewage water has been diverted from falling into Pushkar Lake and polluting it. If left unutilised, it is health hazard otherwise a precious resource, if treated and utilised for plantations. Even the total amount required for water resources for 3000 ha.*alone exceeds the total outlay of the project by five times. Yet an effort is being undertaken with a very small cost by introducing water conservation techniques.

The initial outlay for the Indian component of the project in December 1985 was Rs. 11.1 crores for five years came to Rs.30,000 per ha. for a block of five years covering research, development and extension programmes providing at least self employment to one person per ha. on a sustainable basis.

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* @ Rs.1.5 lakhs per ha. it comes to Rs.45,000 lakhs.

The estimated expenditure on Agricultural Research and Extension in developing countries for 1980 was US $1.9 billion in terms of 1979 constant dollars. To reach a level of 1-2% of GDP by 1985 a growth rate of between 10-15% in expenditure on agricultural research and extension would have to be aimed for. The resources available to research and extension in 1985 using such a growth rate would be US $3.4 billion. The political will to invest this much money in agricultural research and extension must first be generated in every developing country. A proposed indicative public sector investment programme in national research services worked out by FAO in terms of 1980 constant US dollars is given in Table 4. The figures do not include expenditure on extension or by the international agricultural research Centres of the CGIAR System:

TABLE 4

CURRENT AND RECOMMENDED EXPENDITURE ON AGRICULTURAL RESEARCH (FAO)

Region	Estimated expenditure in 1980 (million US $)	Recommended Annual Growth	Recommended Expenditure in 1985 (million US $)
Africa South of the Sahara (excluding South Africa & Namibia)	186	13	343
Asia and the Pacific	175	15	352
North Africa, Middle East and Southern Europe	155	13	286
Latin America and the Caribbean	385	13	709
Total :	901		1690

In Africa, 3 International Research Institutes are being supported under the CGIAR system. These are:

a) International Institute of Tropical Agriculture, Ibadan, Nigeria;

b) International Livestock Centre for Africa, Addis Ababa, Ethiopia;

c) International Laboratory for Research on Animal Diseases, Nairobi, Kenya.

While these Institutes play a useful role in developing concepts, material, bibliographic and seminar services, it is only strong national research systems that can help in rendering the needed support to farmers as and when new field problems crop up. Without a dynamic and well-supported national research system, it will also not be possible to derive full benefit from the research work done in international or developed countries' institutes. This position has been recognised by the CGIAR as the following statement from the 1980 brochure of CGIAR clearly indicates:

> "The yield disadvantage of the tropical and sub-tropical countries cannot be overcome simply by transferring technologies from the temperate zone. The typical developing-country farmer faces problems and constraints for which temperate-zone solutions are often inappropriate and ineffective. The developing-country farmer, for example, typically tills fewer than five hectares; fewer than three in much of Asia; fewer than two in Bangladesh. What soil he has may be low in fertility and poor in structure. He is likely to have too little water or too much, and at the wrong time. The tropical heat bakes his soil, enervates his seeds, and withers his plants.
>
> His seed is usually a traditional local variety, saved from the previous harvest. Its great virtue is

its ability to yield modestly but dependably under difficult conditions with rudimentary management. However, it lacks the genetic potential to reward fertiliser, water, and care with increased yields. Even if the farmer has access to fertilizers and other inputs, he may not have the cash or the credit to buy them, the information to use them to advantage, or the equivalent to apply them. Even if he manages to produce a surplus, he may lack access to markets at prices that will repay his investments."

Thus, local solutions will have to be found for local problems. For building an effective national research capability, three conditions must be fulfilled in the area of personnel policies:

(a) Introduction of personnel policies which can help to attract and retain talent;

(b) Replacing a "post-centred" salary structure with a "scientist-centred" system, so that life-long specialisation is possible without suffering financially as a consequence; and

(c) Introduction of a package of incentives to reverse the drain of brains from villages to cities, thereby making it possible to organise location-specific research.

Normally issues relating to brain drain are discussed only in an international concept. The more serious form of brain drain that agricultural and rural development faces is the drain of brain and resources from the village to town and city. Unless brain and brawn are married in rural professions, stagnation of rural economies will persist[27].

(b) Package of services - In order to develop a meaningful package of services, it will be necessary to undertake in each area and farming system an inter-disciplinary constraints analysis of the kind shown in Figure 3. Such an analysis will help to identify the precise constraints which are responsible for the prevailing gap between potential and actual yields in each farming system. As I had stressed, while discussing the contrasting features of the super-farm and small farm situation, it is essential that the specific needs of small farmers are met through appropriate institutional devices. The package of services should also take into consideration the special needs of women who play such an important role in agriculture. In fact some studies indicate that the process of modernisation of agriculture may cause additional hardships to women, who play such a strategic role in food production, processing, handling, distribution, preparation, and consumption. The extension of cash crops - usually in the hands of men - to the detriment of food crops has often resulted in undernutrition, affecting especially women and children. Agricultural extension programmes for women directed at improving the production of food crops for family consumption, food preservation techniques, and storage facilities, have started receiving attention only in the past few years. Lack of access to appropriate technical information and equipment for home, farm, and market has limited women's participation in the development process, and their ability to increase their efficiency. Case studies in Gambia, for instance, show that women's working time in agriculture rose from 19 to 20 hours when "improved methods" were introduced, while men's working time fell from 11 to 9 hours.

Analysis of 6 case studies summarised in a recent issue of "Assignment Children" has shown that the following three aspects should be kept in view while promoting agricultural and rural development strategies in rural areas (28):

1) Women's overwork and their lack of time;

2) The necessity for income-generating activities if women are to meet their children's essential needs;

3) The fact that none of the income-generating projects is integrated into an overall government strategy for economic development, but all remain marginal activities more related to social welfare concerns.

It is in this context that a household approach to poverty alleviation becomes important. Delivery systems which can reach the target group families will have to be designed in accordance with the needs and possibilities of each area and farming system.

(c) Package of public policies - When agriculture advances, more and more farmers will have something to offer to the market. When this transition from a strictly home need-based to a market-centred land use system happens, the public policy package will hold the key to further progress. Violent undulations in production can be caused not only by the failure of rainfall or by pest epidemics but also by the failure to assured remunerative marketing opportunities to farmers. Wherever land is individually owned, the farmer's decision making on both cropping pattern and input use will be based on considerations of cost, risk and return. In commodities subjected to the vagaries of the international market, suitable national policies like the building up of buffer stocks where appropriate, will have to be introduced to insulate the grower from price fluctuations. Fortunately, the energy crisis has once again re-established the supremacy of many natural products in the world market. Thus natural rubber, cotton, jute and many medicinal and aromatic plants are all gaining in importance once again.

Tropical and sub-tropical countries which can grow a wide range of crops should take full advantage of this emerging trend.

Under conditions where the majority of cultivators are exceedingly poor with very little asset base, suitable measures in the field of agrarian reform are obviously essential before the interests of farmers in undertaking increased production efforts can be stimulated. In regard to asset base, we find two contrasting trends in South Asia and in Africa. In Africa, the availability of vast land resources permitted the inhabitants to resort to the extensive use of various kinds of grazing animals like cattle and sheep in the Savannas and brousing animals like camels and goats in the Steppe and desert zones. Raising of crops was done primarily to meet home needs. An increase in human and animal population leading to the unscientific use of natural resources has, however, resulted over a period of time in the deterioration of the production and recuperation capacity of land and vegetation. The incidence of diseases like trypanosomiasis and East Coast fever in the more humid regions have also led to a greater concentration of animal population in the drier areas, thereby further compounding the problems caused by low and uncertain precipitation and high evapo-transpiration. Crop production became the subsistence sector of the economy while livestock production formed the commercial sector in several parts of Africa. Consequently, value systems in property ownership evolved in conformity with resource endowments. While land was owned by the whole community, individuals owned livestock. Therefore, those who owned larger herd of cattle or flock of sheep could appropriate a greater share of common property. Improvements in veterinary services and facilities for watering also led to a significant increase in livestock population. Consequently the ecological equilibrium attained through a careful balancing of the utilisation of natural resources came under severe stress.

In South Asia, in contrast, land is individually owned in most countries other than China and Vietnam. The land-man ratio is becoming more and more unfavourable with the growth in population. During the past two decades, labour forces engaged in agricultural production in countries of South and South-East Asia increased at the rates of 1 to 2.5% per year. Meanwhile arable land area increased at the rate of about 1% or less except in Thailand. Consequently the man-land ratio increased. More importantly, the increase in the man-land ratio accelerated from 1955-65 to 1965-75, reflecting the rapid exhaustion of hitherto unused land for cultivation. In the latter decade, the man-land ratio grew rapidly, on the average at a rate of doubling the number of workers per hectare within a half century. The deterioration in the land-labour ratio is even more serious than would appear from statistical data because the frontiers of cultivation have been extended into marginally less productive areas. In several parts of India, the average size of an operational holding is even now one hectare or less. Therefore, in many countries of Asia land reform legislation involving measures in the area of ceiling to land holdings, re-distribution of ceiling surplus land, security of tenure and minimum wages become essential for providing a long-term stake on the land to the cultivator and for protecting the interests of share croppers and landless labour.

In contrast, re-distribution of the livestock among individual families and ceilings on livestock ownership in order to assist in matching the livestock population to the carrying capacity of land will be necessary in several parts of Africa. The public policy package necessary in Savanna countries for livestock reform needs to be gone into carefully. In some countries both land and livestock reform will be necessary, while in others either land reform or livestock reform alone may be needed.

Another area which needs to be carefully looked into is the marketing system. Quite frequently, producers of crop, livestock and fish products tend to get only a small proportion of the price paid by urban consumers. Similarly primary producers, whether farmers or fishermen, tend to derive very little benefit out of thriving export trades developed in both cash crops and marine products. Producer-oriented marketing and consumer-based distribution will be essential to stimulate production and consumption. This is an area which needs integrated attention, since steps designed to stimulate production by giving high incentives to farmers alone could become counter-productive if the consumption base becomes even more skewed than it is already with regard to different income groups, because of a further shrinkage in the consumption levels of the rural and urban poor.

Given an appropriate blend of technologies, services and public policies, it will be possible for every country to derive the maximum benefit from its agricultural assets and minimise the hazards arising from factors beyond human control.

VI. AGRICULTURE AND FUTURE OF MANKIND

"Sweet Peace, where dost thou dwell?
I humbly crave,
Let me once know.
I sought thee in a secret cave,
And ask'd, if Peace was there,
A hollow wind did seem to answer, No:
Go seek elsewhere.
At length I met a rev'rend good old man:
Whom when for Peace
I did demand, he thus began:"

....

"Take of this grain, which in my garden grows,
And grows, for you;
Make bread of it: and that repose
And peace, which ev'ry where
With so much earnestness you do pursue,
Is only there."

... George Herbert.

The linkages between agricultural advance, industrial production and socio-political stability have been long recognised. While there has been certainly great progress during this century in increasing food production, the progress has been uneven with reference to regions, crops and categories of farmers. The fluctuations in production have also been too wide to provide the necessary margin of safety. The need for a global food security system which will help to insulate the human race from the threat of hunger and famine has also been realised and stated in many world conferences including the World Food Congress held in Rome in 1974. Sharp rhetoric at such conferences do not, however, shorten the steps needed to build such a system. Past experience teaches us that mutuality of self-interest can alone provide the necessary motivation for enduring co-operative action by nations.

Fortunately we now find several common denominators emerging which could provide the basis for global co-operative action.

First, different nations are blessed with different natural endowments. Thus countries which were once regarded as hopeless deserts have now thriving economies as a result of their fossil fuel reserves. Similarly countries in the tropics and sub-tropics which were formerly considered as agriculturally backward and even classified on the basis of the triage principles into relative grades of hopelessness are now known to have the potential for becoming major 'green power' countries because of their endowments of sunlight and water. Hence, our spaceship earth is so structured that different components of it have complementary strengths. Secondly, the basic life support systems in the world constitute in a way a common heritage. The tropics and sub-tropics again constitute the major reservoirs of genetic variability in crops and farm animals. The temperate countries in contrast have developed methodologies for collecting and maintaining for posterity such variability. Global atmospheric effects like enhanced CO_2 concentration would affect all countries in an adverse manner. Barbara Ward in her book "Progress for a Small Planet" has explained these linkages lucidly and convincingly (29). Therefore, at least on considerations of survival, nations, whether poor or rich, will have to develop a system of organised co-operation based on principles of symbiosis and synergy. I, therefore, feel that we should continuously seek and identify areas which will bring nations together irrespective of their political ideologies into a working partnership just for the purpose of saving our spaceship earth from annihilation. How can we work towards achieving this objective? I feel that to start with, each nation should begin a well planned and sustained effort in building a national food security system. Such a system should have the following 5 major components:

(a) Ecological Security - Steps for achieving ecological security would include measures for protecting all the basic assets of agriculture and minimising the liabilities. As I had mentioned earlier, this can be achieved through the establishment of a National Land Use Board which could foster through appropriate scientific analysis and public policies, land and water use practices which are compatible with the concept of sustainable development. Ecological security, however, cannot be promoted by Government alone. It has to be a joint sector activity involving the people and government agencies. Local level Eco-Development Associations should be organised with the involvement of schools and colleges. Such Associations could operate 'Waste Exchanges' to collect and re-cycle all organic wastes. The economic benefits from eco-development and waste re-cycling could provide the motivation necessary for attracting public attention and participation. For example, in the United States it has been calculated that an estimated 300 million trees could be saved annually if the amount of paper recycled is trebled. Besides steps at the national level, regional and global level action plans to conserve our genetic and environmental heritage need to be developed. Some steps like the organisation of an International Bureau of Plant Genetic Resources have already been initiated but many more such steps are needed.

(b) Technological Security - Growth with stability should be the aim of agricultural development programmes. These would call for breeding of high yield-cum-high stability varieties and similar measures in animal husbandry and fisheries. The research system should also have the capacity for promoting appropriate early warning-cum-timely action programmes. Pest survey and surveillance systems as well as soil, water, plant and animal health care programmes will have to be developed. Here again, the total involvement of

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the local farming community will be necessary. Since in the case of pest epidemics, political boundaries would not provide the basis for appropriate early warning and control systems, it will be necessary for all the countries concerned with the problem to get together and form a regional control grid. The F.A.O. sponsored programme on locust control is a good example of the value of such cooperation.

(c) Post-harvest Technology and building grain reserves - A mismatch between production and post-harvest technologies frequently result in losses both to the producer and the consumer. Therefore, all aspects after harvest, such as drying, storage, processing, transport and marketing will have to receive integrated attention. Depending upon possibilities, every country should maintain a reasonable grain reserve. India, for example, derived immense benefit during the unprecedented drought year of 1979 from the grain reserve of about 20 million tonnes built up by the Government. A decentralised strategy of grain storage would also help under conditions of a free market economy to prevent panic purchase when conditions for crop growth are unfavourable and distress sale by poor farmers with no holding capacity when the harvests are good. In fact a decentralised plan for storing grain as well as water at appropriate locations all over the country should be an essential element of the food security system of nations whose agricultural fortunes are closely linked to rainfall distribution.

(d) Social Security - In many developing countries, grain surplus and widespread hunger tend to co-exist. Even when there is food in the market, the lack of purchasing power leads to undernutrition and malnutrition. Therefore, in countries where agricultural production keeps ahead of population growth, the food and nutrition problem could be better stated in terms of mandays of employment rather than in metric tonnes of foodgrains. Right to work should hence become an integral part of the plan for food security. This is why the integration of

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employment generation as an explicit aim in land and water use plans assumes relevance. Social security measures should include programmes like 'Food for Work' for able bodied persons, 'Food for Nutrition' for young children, pregnant and nursing mothers, old and infirm persons, and rural development programmes designed to provide the minimum needs in the field of drinking water, education, health and environmental sanitation. In addition, there has to be a detailed employment generation strategy based on a careful analysis of the possibilities for -

(i) land and water-based occupations, such as agriculture, horticulture, animal husbandry, fisheries and forestry;

(ii) non-land occupations like small and village industries as well as agro-processing enterprises and

(iii) provision of relevant services.

The services sector tends to provide in developed countries great opportunities for employment. In fact as agriculture advances, more and more persons working on a daily wage status tend to get employed in the secondary and tertiary sectors of the economy. Historically, a rising standard of living has depended on the ability of agriculture to release manpower to other more industrial pursuits.

(e) Nutrition Education - Even when people have the requisite purchasing power, there may still occur several forms of nutritional diseases arising from specific causes such as vitamin 'A' induced blindness, iron deficiency anaemia, goitre, etc. Such nutritional disorders attributable to well-identified causes can be easily eliminated within a specific time frame through concerted efforts in nutrition education and intervention.

When all the above five groups of programmes get well integrated into overall national and regional action plans, we will see the emergence of a strong national food security system. It would be advisable in all countries where the food-population equation is not favourable, to have at the Cabinet level a Committee on Food Security to provide the necessary political and policy guidance to ensure the involvement of administrative, academic and local communities into a well-coordinated and co-operative action programme.

It is my conviction that only when all countries pay serious attention to building their respective national food security systems that an International Food Security System will emerge. For organised and mutually beneficial growth of agriculture in different parts of the world, there is need for some form of international agricultural adjustment programme. For example, the F.A.O. has recently proposed the following 12 guidelines for promoting agricultural adjustment among nations (30);

1. Food and agricultural production in developing countries as a whole should expand during the Third UN Development Decade by an annual average rate of at least 4 percent a year. To complement the efforts of developing countries and having regard to their special needs and interests, developed countries should manage their production capacity in agriculture and expedite structural changes. All countries should promote a rational world-wide production pattern.

2. The total flow of financial and other resources to food and agriculture in developing countries should be greatly increased. Substantial increases in research, both national and international, should be paralleled by special efforts to increase the efficiency of use of resources and existing technologies.

3. Developing countries should give priority to programmes for adaptation of institutional frameworks and farming structures so as to allow wider and more equitable access to:

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- land, water and other natural resources;
- inputs, markets and services;
- new and improved technology;
- education, extension, research and training;

and provide incentives through appropriate policies, including price policies, for expanded use of inputs and for optimum use of available and suitable technology.

4. National policies for agricultural and rural development should include full and effective participation of rural people in decision making, implementation and evaluation of the process of agrarian reform and rural development through promotion of peoples' organisations and by strengthening of local government. Full integration of women in rural development on an equal basis should be encouraged.

5. All countries should establish integrated food and nutrition policies. Within the framework of national development strategies, developing countries should set operational goals for the improvement of consumption patterns and for the reduction of malnutrition. Nutritional considerations should be incorporated into the design, planning, implementation and evaluation of development projects.

6. Developing countries should implement special economic and social measures including, wherever appropriate, public food distribution and subsidy systems so as to expand food consumption of low income consumers and to improve nutritional levels of under-nourished segments of the population, especially vulnerable groups. Better utilization of food will require greater efforts to reduce food losses and to improve storage, processing, transport, marketing and quality of food.

7. All countries, and especially developed countries, should refrain to the maximum extent possible from imposing any new tariff or non-tariff barriers to the imports of

agricultural and agro-based products and they should progressively improve access to their markets in order to underpin a dynamic upward trend in trade volumes in these products as well as greater product diversification.

8. Exporting countries should take all possible measures to enable importing countries, particularly developing countries, to be assured of access to supplies of food and agricultural inputs on reasonable terms and without adversely affecting their economic development, particularly in times of large-scale food shortages.

9. Developing countries should examine the ways of promoting trade among themselves in food and agricultural commodities, gradually build up a viable framework and adopt appropriate operational measures.

10. World cereal stocks should be maintained at an adequate level, which has been estimated at from 17 to 18 percent of the annual world consumption. Early consideration should be given to the introduction of a reliable concessionary food financing facility for meeting the rise in food import bills of deficit developing countries in the event of domestic food shortages or rising import prices and an International Emergency Reserve, with guaranteed resources of at least 500,000 tons of grains, under a legally binding convention. The management of domestic policies of developed, importing countries should be such as to moderate their demands on world markets in times of scarcity.

11. Current targets for food aid should be fully met. As future requirements will be substantially larger than the current target of 10 million tons of cereals, urgent consideration should be given to their upward revision.

12. External assistance to developing countries must be substantially increased for the adjustment of international

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agriculture. Earlier estimates of annual development assistance requirements of $8.3 billion (in 1975 prices) will need to be raised significantly.

I have cited these suggested guidelines to indicate the kinds of action needed at the national and international levels. An awareness of the urgency of such steps has led to analysis of the situation at global meetings. Will analysis lead to action rather than to paralysis? If we really believe that a new international economic order is necessary, action should not be delayed any further, since the basic life support systems are getting damaged beyond repair. Even if the guidelines cannot be implemented all at once, continuous efforts to achieve these aims rather than despair and inaction should be the response of all national governments. In such a global endeavour, the following words of W.H. Auden should serve as inspiration for action and thereby for agony to lead to ecstasy:

"Hunger allows no choice
To the citizen or the police.
We must love one another or die .....
Defenceless under the night
Our world in stupor lies;
Yet, dotted everywhere,
Ironic points of light
Flash out wherever the Just
Exchange their messages;
May I, composed like them
Of Eros and of dust,
Beleaguered by the same
Negation and despair,
Show an affirming flame."

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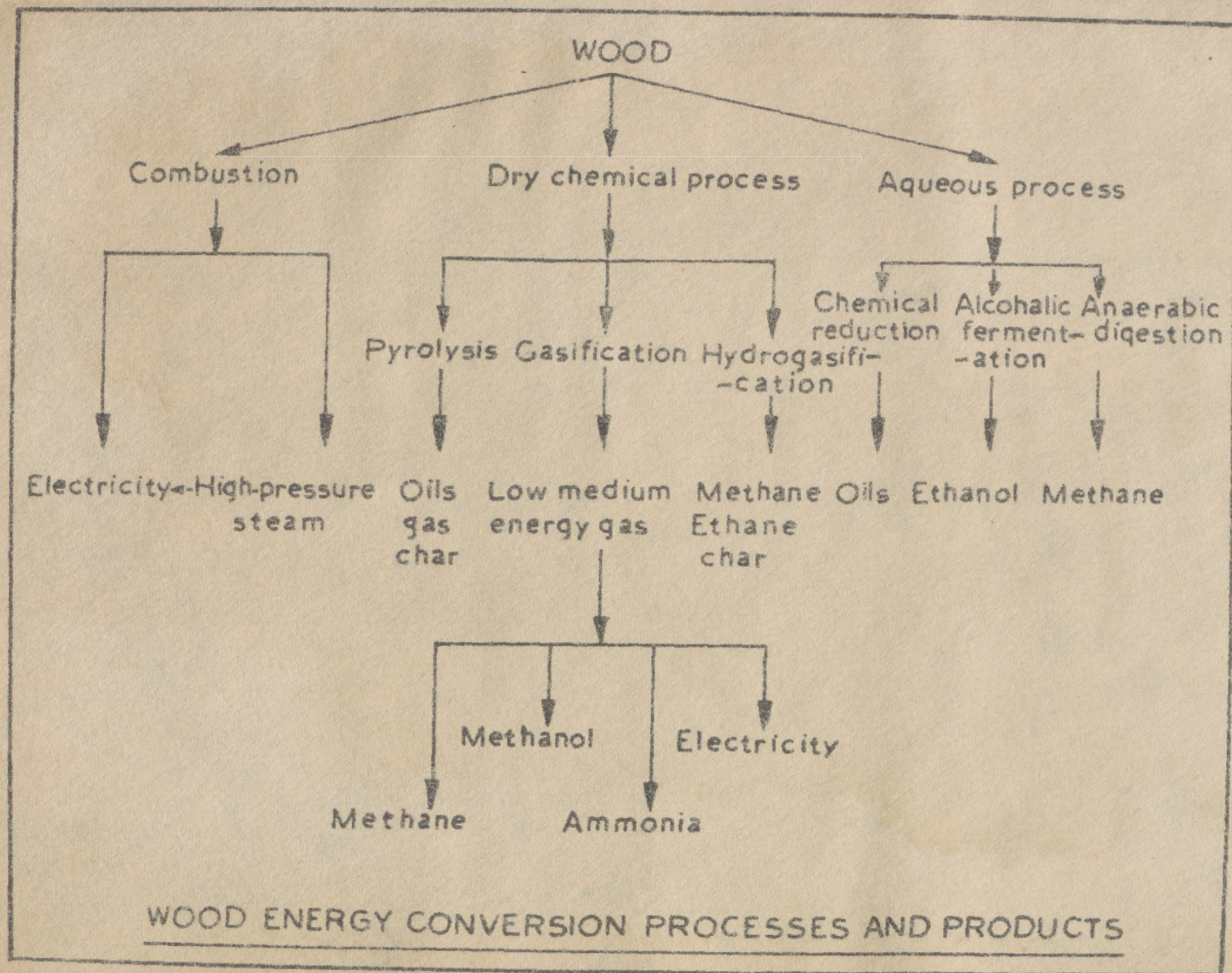
WOOD
Combustion
Dry chemical process
Aqueous process
Pyrolysis
Gasification
Hydrogasifi- -cation
Chemical reduction
Alcohalic ferment- -ation
Anaerabic digestion
Electricity
High-pressure steam
Oils gas char
Low medium energy gas
Methane Ethane char
Oils
Ethanol
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Methanol
Electricity
Methane
Ammonia
WOOD ENERGY CONVERSION PROCESSES AND PRODUCTS

Fig. 1

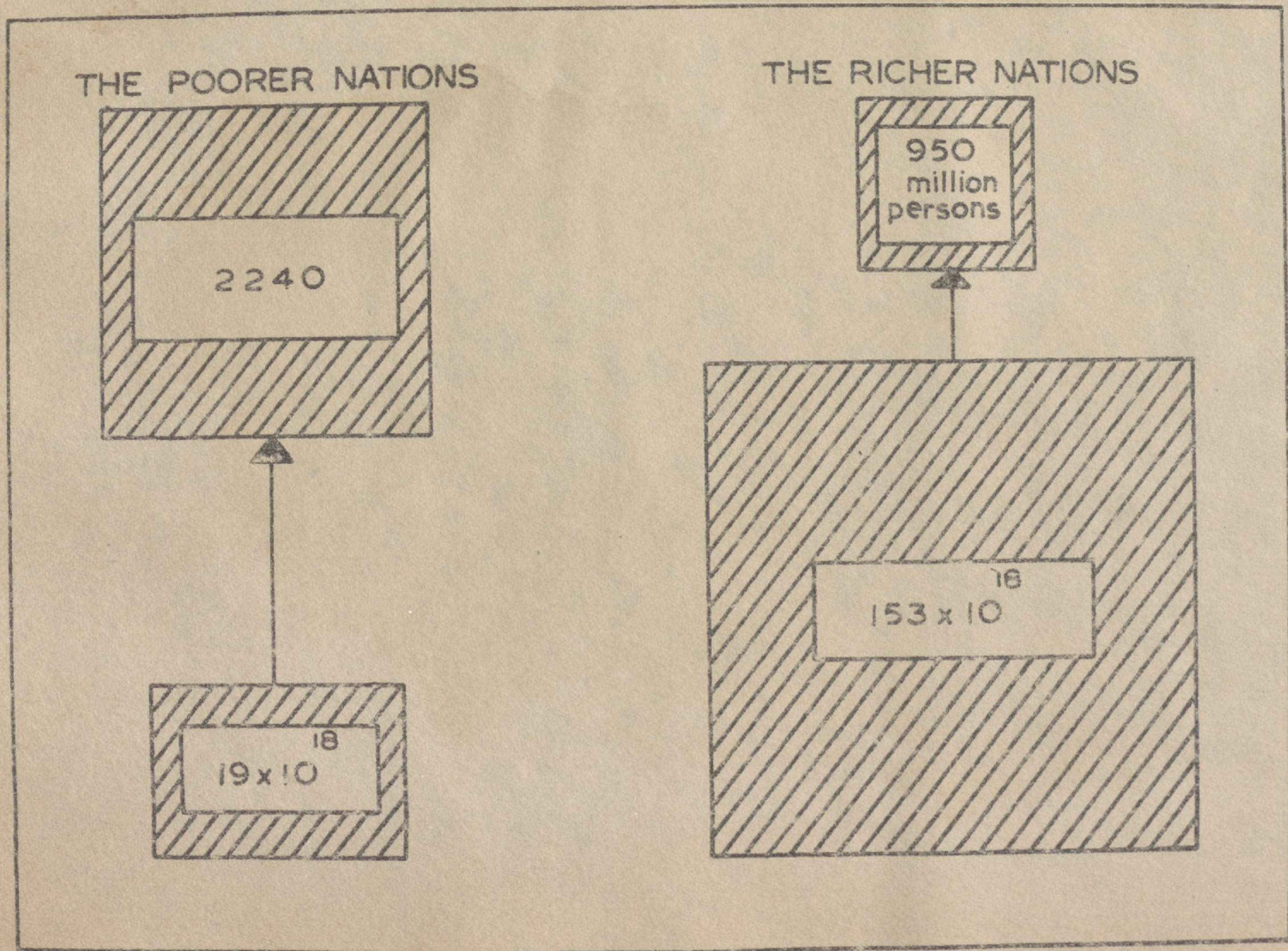
THE POORER NATIONS
2240
19 x 10 18
THE RICHER NATIONS
950 million persons
153 x 10 18

Fig. 2

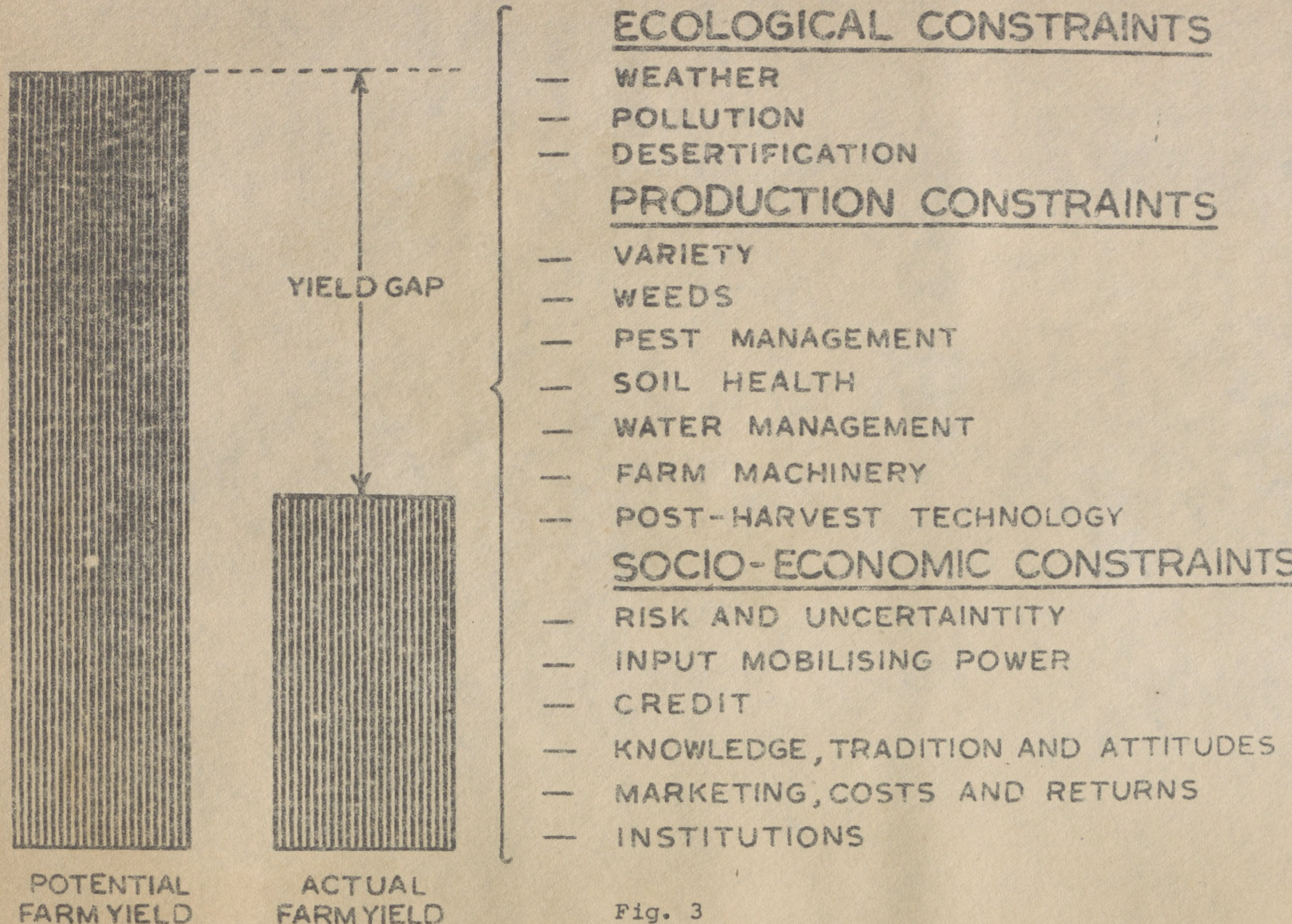
YIELD GAP
POTENTIAL FARM YIELD
ACTUAL FARM YIELD
ECOLOGICAL CONSTRAINTS
— WEATHER
— POLLUTION
— DESERTIFICATION
PRODUCTION CONSTRAINTS
— VARIETY
— WEEDS
— PEST MANAGEMENT
— SOIL HEALTH
— WATER MANAGEMENT
— FARM MACHINERY
— POST-HARVEST TECHNOLOGY
SOCIO-ECONOMIC CONSTRAINTS
— RISK AND UNCERTAINTITY
— INPUT MOBILISING POWER
— CREDIT
— KNOWLEDGE, TRADITION AND ATTITUDES
— MARKETING, COSTS AND RETURNS
— INSTITUTIONS

Fig. 3

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I. Introduction

"Count your blessings" is an old adage. Sunlight, water, soil, flora and fauna besides the atmosphere are the basic endowments upon which human civilization rests. It is in Africa that the first human form was born, some 25 million or more years ago. The remains of hominids like Zinjanthropus, one of the earliest known toolmakers, were discovered by Drs. Lois Leakey and Mary Leakey at Olduvai Gorge in northern Tanzania (1). It took many million years, however, before modern man *Homo sapiens* evolved. In addition to the blessings of nature, *Homo sapiens* was blessed with brain power. Brain power led to new blessings, agriculture being the greatest among them. About 10,000 years ago, women probably started growing plants while men went out hunting for food. This transition from food gathering to food growing also marked the beginning of many important changes in human civilisation. Nomadism was replaced by settled life. Various forms of cultural energy were introduced to supplement solar energy in order to get higher and more stable yields. Crop husbandry and animal husbandry evolved together in some parts of the world as mixed farming systems or separately in the form of pastoral and arable land economies. Land and/or livestock became symbols of wealth.

The origin of settled cultivation was beset with many problems which the early cultivators solved by methods which then appeared to be the most sound and feasible. Some of these problems were:

1) Pest and disease epidemics arising from monoculture of a few crops: For example, although the native flora and fauna consist of over five million species, hardly 30 species are in use for meeting a large proportion of the food needs of the people. The vulnerability of food

production systems to pest epidemics gets further enhanced by restricting the cultivation to a few selected strains of each species. It is, however, a tribute to the observation power of the early agriculturists that 20th century man has not been able to make any significant addition to the list of commercially important plant or animal species.

2) Soil fertility: The restoration of soil fertility became a problem after a plot of land has been cultivated continuously with crops for a few years. The law of diminishing return with regard to soil productivity posed a threat to settled cultivation.

3) Desertification: Soil erosion, salinization, waterlogging and other problems tended to either diminish or destroy the biological potential of land.

4) Storage: Storage of surplus produce presented serious problems. Solar dehydration and numerous innovations in storage structures helped to prolong the shelf life of both grains and perishable commodities.

Shifting cultivation was found to be a feasible answer to problems arising from soil fertility depletion and pest incidence. Later, other practices like cereal-legume rotations and the application of organic manures got incorporated into farm practices. The discovery of mineral fertilisers during the 19th century finally helped in developing procedures for soil fertility management designed to render the law of diminishing return irrelevant with regard to soil productivity. In spite of the progress made and innovations introduced prior to the beginning of this century, crop production tended to remain a gamble in the rain. Aberrant weather and pest epidemics tended