AGRICULTURE IN THE EARLY XXI CENTURY:
Agrodiversity and Pluralism as a Contribution to Address Issues on
Food Security, Poverty and Natural Resource Conservation

Reflections on its Nature and Implications for Global Research

Final Version

Issues Paper Commissioned by the GFAR as a Basis to Elaborate a Global
Shared Vision on Agricultural Research for Development

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Contents

INTRODUCTION: DEVELOPMENT OF A GLOBAL SHARED VISION 2025.............................1

1. AGRICULTURE AND FOOD SECURITY IN THE LAST DECADES..........................................1

2 GLOBAL TRENDS AFFECTING AGRICULTURE.........................................................................2

   2.1 TRADE GLOBALISATION......................................................................................................3

   2.2 THE NATURE OF FOOD DEMAND...........................................................................................4

   2.3 PERSISTENCE OF POVERTY...................................................................................................5

   2.4 FOOD PRODUCTION................................................................................................................5

   2.5 ENVIRONMENTAL CONCERNS...............................................................................................6

   2.6 SCIENCE AND TECHNOLOGY.................................................................................................7

   2.7 CHANGES IN THE ROLE OF THE PUBLIC SECTOR AND CIVIL SOCIETY......................8

3. IMPACTS OF GLOBAL TRENDS ON AGRICULTURE................................................................9

   3.1 ON FOOD SECURITY.....................................................................................................................10

   3.2 ON PRODUCTION EFFICIENCY..................................................................................................11

   3.3 ON POVERTY AND EQUITY...........................................................................................................12

       3.3.1 On People's Wellbeing.....................................................................................................12

       3.3.2 On the Industrial Organisation of Agriculture.................................................................13

   3.4 ON ENVIRONMENTAL CONSERVATION.........................................................................................15

       3.4.1 On Land Pollution and Human Health...............................................................................15

       3.4.2 On Land Degradation........................................................................................................16

       3.4.3 On Water Availability........................................................................................................17

   3.5 ON THE DYNAMICS OF RESEARCH AND DEVELOPMENT SYSTEMS.................................................18

4. REFLECTIONS ON TRENDS AND IMPACTS............................................................................20

5. TOWARDS A KNOWLEDGE AGRICULTURE........................................................................20

   5.1 TECHNOLOGICAL DEVELOPMENT PATTERNS.......................................................................20

   5.2 A KNOWLEDGE-DRIVEN PATTERN ...........................................................................................ERROR! BOOKMARK NOT DEFINED.

   5.3 CHARACTERISTICS OF KNOWLEDGE-BASED AGRICULTURAL MODELS...........................................22

       5.3.1 The Technical Dimension....................................................................................................23

       5.3.2 The Socio-Economic Dimension.........................................................................................24

       5.3.3 The Institutional Dimension.............................................................................................25
5.3.4 The Policy Dimension.......................................................................................... 27
5.4 The Potential of Knowledge Agriculture............................................................... 29

6. Towards a Global Research Agenda................................................................. 30

6.1 Areas of Research............................................................................................... 31
6.2 The Global Research System............................................................................. 33

7. References........................................................................................................... 35
Introduction: Development of a Global Shared Vision 2025

One of the first tasks carried out by the Global Forum on Agricultural Research (GFAR) is the formulation of a Global Shared Vision (GSV) for Agricultural Research for Development (ARD). The purpose of the GSV is to potentiate and orient international agricultural research in coming decades, as a way to mobilise the scientific community around the general objectives of poverty eradication, increasing food security and conservation and management of natural resources.

In this context, the present Issues Paper is assigned the functions of:

- Explaining the environment in which the “GSV Statement” is prepared;
- Analysing the most significant changes and trends in GFAR’s context;
- Interpreting the scope of the Vision.

This Paper is also expected to elaborate on the rationale behind the Shared Vision, and establish the basis for a Plan of Action to implement it. It is important to point out that this document is accompanied by two other documents: (a) The Global Shared Vision Statement (2 pages), and (b) Global Forum on Agricultural Research: The Next Steps. While the first document presents the vision, the second document presents a proposal for an implementation strategy, in order to operationalize the GSV through the five priority areas that have been identified for international cooperation in ARD.

The paper covers a wide range of themes and issues. The main objective and intention is to serve as a starting point of a discussion on the major trends of world agriculture and their implications for a global research agenda. The proposals in relation to a Knowledge Agriculture and the possible research areas are tentative in nature and need to be collectively examined.

1. Agriculture and Food Security in the Last Decades

   After World War II there was an extended belief that population growth and food demand would increase faster than food production. In a way most people had a Malthusian view of the world food situation.

   The seventies and eighties proved that those expectations were wrong. Food production increased, worldwide, at more than 3 percent per year, improving food availability and forcing down world prices of the major commodities.

   Agricultural research developed in the industrialised countries, research and extension by the NARs and the important contributions of the CGIAR Centres to the development of the green revolution, is one of the main explanations of this extraordinary success in agricultural production.
The economic political and human importance of this success can not be overestimated. In the absence of the green revolution, hunger and malnutrition would be widespread in large regions in the world, and regional social conflicts, many of them closely related to access to natural resources and food, would be more frequent of what they have been. It is for these reasons that the historical importance of the green revolution has to be measured within the context of the food situation most prevalent during the middle of the century and against its very important impact in alleviating potential human suffering.

However, and in spite of this success, it is important to stress that food security has not been attained around the world. About 20% of world population receive less than the required calories for a productive life. Much of this undernourishment is concentrated in some regions, mainly Subsahara Africa and some countries of South Asia. In addition now, after several decades of agricultural growth based in yield increases in a small number of crops cultivated under heavy use of fertilizers and other industrial inputs, new problems are beginning to emerge. Some of these problems are related to environmental pollution, natural resources degradation, persistency of rural poverty and to an increasing concentration of economic resources in the hands of a few.

These problems are consequence of the development pattern that has emerged in most of the world, including the characteristics of agricultural modernisation. Although some of the global trends which led to this type of development are likely to continue in the future, there are new opportunities and alternatives that need to be explored to take forward the implementation of the global shared vision.

2. Global Trends Affecting Agriculture

The globalisation of human activity is, one of the major aspect that need to be taken into consideration in the analysis and discussion of future trends. It involves a dramatic process of putting ideas, people, activities, sectors, nations, blocks in contact with each other in a context of also increasing interdependency. The most prominent of these processes is the global interconnection of financial markets, trough which every day flow more than $1.5 billion. Physical trade has also increased significantly: towards the end of the century goods and services traded amounted to about one fifth of the total output of the planet. Financial markets and trade, however important, are just part of the process, globalisation goes beyond the economy into culture, technology and even government structures; its essence is the ever growing interdependency of economics activity. The process is not new, it has been going on since the renaissance, what is new is the extent of human activities involved today and the intensity with which it is evolving. Globalisation in the late twentieth century also implies new institutional actors, such as the OMC with powers above the national states, transnational corporations, economically larger than many countries following their own logic of economic gain and a fast growing network of NGO of global reach. Additionally international norms and regulations, such as the multilateral agreements on trade, services, IPR, bio-diversity conservation, etc, which are rapidly creating new
obligations, restrictions and opportunities for those more able to participate under the new conditions. The growing economic interdependence has also implied a greater homogenisation of consumption patterns and social aspirations. However these processes are not in themselves homogeneous across the region or social boundaries. Income distribution, access to information and resources and the capacity to adapt to the new circumstances are not equally distributed.

In this environment there are some specific elements that have a special impact on agriculture affecting its future evolution. The main trends that affect agriculture refer to: i) trade globalisation; ii) the nature of food demand; iii) the persistency of poverty; iv) food production; v) environmental concerns; vi) science and technology; vii) changes in the role of the Public Sector and Civil Society. It should be emphasised, however, that even though these trends are global in nature, its evolution and, consequently, their impacts are not the same for all developing regions or social groups. Urbanisation, for instance, is a process evolving at a much faster pace in Latin America and the Caribbean, than in countries of Asia and Africa or South of the Sahara in Africa; the effects of trade liberalisation will also vary among countries and regions according to the structure of their agricultural production and their level of integration into the international markets; and, issues related to the privatisation of knowledge are of greater importance in the larger economics of Asia and South America than for countries in Africa or Central America. On the other hand a large percentage of world population, and specially the rural poor have not benefited from globalisation and in many cases they have been negatively affected, as the specialization normally associated with globalization weakens a community’s control over its livelihood, and reduces the range of choices on ways for people to make a living.

2.1. Trade Globalisation

Although trade in goods and services is not expanding at the same pace as international financial flows, which have grown from about $8 billions in the 1970s to $167 billions a year in the 1990s (more than 3% of global GDP), it has also experienced significant increases, more than doubling its volume in all major categories, including agricultural commodities. This trend is expected to continue during the early decades of this century. According to IFPRI poultry and beef trade are projected to go up by 22% and 187% respectively, while rice trade will increase by 139%, soybeans by 121%, coarse grain by 62%, wheat by 61%, maize by 37% and roots and tubers by 29%.

In principle, an expanded trade system would improve food security by increasing the access to food around the world. There are, however, a number of aspects that need careful consideration, as the structure of trade flows is changing in parallel to the increased trade levels, and not all the countries and segments of the agricultural economy will benefit in the same way.

The participation in global trade of the poorest countries representing 20% of the world population, has fallen from a 4% in 1960 to a 1% in 1990, while the share of world exports going to the developing countries has grown from 13% in the early 1970s
to more than 26% in the 1990s. At the same time trading activities are concentrating in the hands of a small number of companies (Fig. 1). Both tendencies should be taken as an early warning of possible biases in the distribution of the economic benefits of the globalisation process.

Expanded trade, is also pressuring countries to seek cost reduction to maintain their competitiveness in attracting mobile capital. There is the risk that in the absence of clear international agreements for all countries to internalise their environmental costs in search for a “sustainable free trade”, there would be a tendency to attempt to increase competitiveness through low environmental and social standards, and not through an increase in the efficiency of food systems. It should also be mentioned that this efficiency is being affected by an increasing consumption of fuel for processing and transporting food products around the world, which impinges upon environmental quality.

2.2. The Nature of Food Demand

Population, income growth and the rate in urbanisation, are redefining the level and nature of food demand. According to IFPRI, the most likely scenario for the next 20 years is one of a significant increase in the demand of all major food categories. Cereal demand expected to go up 39% to reach 2466 millions tons, meat demand will increase by 58% to a level of 313 million tons, while roots and tubers demand will reach 864 million tons, an increase of 37% over 1995 levels. The major force behind this change will be population growth which expected to average about 73 million people a year to take global population to a level of 7.5 billion by the year 2020. Most of this increase will take place in the developing world, about 97.5% of the total, with Asia showing the largest absolute increase – 1.1 billion people – and Africa the most important relative change with an increase of 70% over present levels.

Urbanisation is rapidly becoming the predominant pattern for human settlements throughout both the developed and the developing world. At the turn of the century about one half of the world population is already living what are considered urban areas, but by the year 2025 it is estimated that two third of the population will be living in the cities, up from only about one third in 1975. In the developing world, however, total rural and urban population will be at about the same level by the year 2020 (Fig. 2). It is expected that in the next 20 years people living in the urban areas around the globe will increase 1.5 billion, to about 3.4 billion. Just the same to what is happening with total population trends, the greatest changes in this sense will be taking place in the developing countries. Even though the rate of urbanisation has already picked in most of the middle income countries in Latin America, eastern Europe and the Middle east, the transition, however, is just beginning in Asia and Africa.

These changes together with rising incomes – total income is expected to increase at an average of 4.4% annually until 2020, implying a doubling of per capita incomes to a level of $2200 – will have dramatic increases in the structure of demand and food systems. Urbanisation brings an increasing separation between what is produced at the
farm level and what is consumed as food, turning farm output into a less important component of food supply, while related processing and transportation services will increase their relative importance in food security strategies. The changes in life style associated with urbanisation and, eventually, rising incomes, will also push food demand towards a more diversified diet, away from coarse grains into rice and wheat, more livestock products, fruits, vegetables and processed foods.

2.3. Persistence of Poverty

Recent world estimates indicate that the number of people living on less than $1 or $2 per day in 1998 (1.2 and 2.8 billion respectively) was almost the same, or larger, than that in 1987 (Fig. 3 and 4). There were, however, changes during this period, as the number of poor declined substantially in the mid-90s, to rise again in the late ‘90s.

Sub-Saharan Africa is the region with the largest share of people living on less than $1/day (46.3%), while South Asia’s share prevails for those living under the $2/day threshold (85.0%). In this region the share of the population living on poverty declined moderately throughout the decade, but not enough to reduce the total number of poor people, which has been rising steadily since 1987 (by 60 million in the decade). In Latin America and the Caribbean poverty rates remained fairly constant throughout the decade (16%), despite the acceleration of growth in the late ‘90s. Finally, in countries of the former Soviet block poverty rose markedly from 1987 to 1996 (from 1 to 24 million), and chronic poverty is emerging as a vital concern.

Prospects for reducing poverty in the coming decade have been analysed under two scenarios (Fig. 5). The so-called A scenario - slow growth and rising inequality - is based on the experience of the last decade, and makes little progress in reducing the total number of poor (from 24 to 22% of people living with less than $1/day). Scenario B - inclusive growth - leads to sustained growth without increases in inequality, reducing by half overall poverty (from 24 to 12%). It is worth mentioning that similar estimates in 1990 forecasted a fall in the global poverty rate from 32.7% in 1985 to 18% in 2000, while the actual fall was from 28.3% in 1987 to 24% in 1998.

2.4. Food Production

World growth rates of cereals production have been steadily declining since the early sixties, from 2.9% in 1967-82 to 1.8% in 1982-94 (Fig. 6). In the period from the early 60s to the late 80s developing countries increased their cereal production by more than 100%, based mainly on the application of science and technology to the development of ‘technological packages’ characterised by monocropping, irrigation, improved varieties and agrochemicals. The remarkable increases in yield were accompanied by an important expansion of irrigated lands (60% in Asia), and fertiliser input (2000% of N-based). Therefore, of the total increases in production only 33% were attributed to the improved varieties, and 66% to the environment-changing inputs (33% to irrigation and 33% to inorganic fertilisers). Since then evidence from a number of experimental and field sites indicate declining yields for the main ‘green revolution’
cereals under intensive cropping on some of the better lands. Part of the reason seems to be the ‘unexpected’ importance of micro-element deficiencies and toxicities, showing the systemic nature of ecological relationships in sustainable agriculture. For the developing countries as a whole the production of high-protein content pulses have also been declining steadily for the last decades. As a result of this tendencies in production, and of higher demands, developing countries that were net exporters of agricultural products a few decades ago are now net importers (Fig 7).

Together with the above, other critical sources of food are also being affected by the technological path followed in the recent past. Estimates show a 60% of the world population receiving more than 40% of their annual protein from fish; and that an 18% of the total world catch comes from rivers and lakes. An increasing success of the high-input package in land-based agro-ecosystems could threaten food production in adjacent aquatic and marine systems; as a consequence of chemical contamination of waters and the corresponding eutrophia in such ecosystems. These negative effects of the high-input agriculture on the capacity of aquatic ecosystems to produce food serve to emphasise the value of a systemic approach to food security; and should be included in the ‘balance sheet’ of production increases achieved on firm lands.

High-input agriculture appears as the main source of this contamination of aquatic ecosystems, as man applies inorganic N at an annual rate of 100 million tons, equivalent to the sum of all biological processes. In areas of high agrochemical use 30 to 80% of the man-made N applied is not used by crops, contaminating waters, the atmosphere, food and forages. N run-off from agricultural soils has been identified as the main source of eutrophication of rivers and lakes in the USA, which, in turn, transport annually more than 40 million tons of N to the coastal marine waters, depleting water of its O2 content. It has been estimated that 52% of the estuaries in that country suffer from a reduction in its O2 content large enough to affect aquatic life, reaching an 85% in the Gulf of Mexico (where 18000 km2 in the mouth of the Mississippi river are already considered to be a ‘dead zone’). Similar interactions have been identified throughout the world and represent one of the major threats to the sustainability of the food supply in the coming decades.

2.5. Environmental Concerns

The effects of soil degradation and water pollution and scarcity on agricultural production and productivity have until now been greatly diluted by both the possibility of incorporating new land into production and by the large and steady growth in yields brought about by the green revolution. Today neither of these processes could be assumed to continue into the future at the same pace that they did during the last half of a century. Moreover, increasing land pressure, and the corresponding cultivation of marginal lands, will lead to further degradation of resource-poor ecosystems, where the majority of the rural poor get their livelihood. In this context, civil society and consumer concerns over natural resource conservation and food safety are increasingly affecting technological practices for food production and processing.
Such concerns refer to the possible effect of agricultural management practices on environmental pollution, global warming, biodiversity, deforestation, water use, health, and even societies’ views on the role of the rural landscape and their eventual consequences on life quality. In this context, in some developed countries, especially European, the view of the rural landscape as primarily a producer of agricultural products is shifting towards that of a provider of “environmental services” essential to their life quality standards.

2.6. Science and Technology

Advances in the fields of biotechnology, communications and information sciences, and agronomy are rapidly defining a new tecno-economic paradigm in developed countries, having profound impacts on their social organisation and production patterns. New boundaries and opportunities are being generated on every field of human activity, and in some agriculture-based economic and social processes are among the most affected by the new developments.

Modern techniques for genetic improvement, specially gene transfer, are bringing about notable progresses to agriculture, that promise to be even more impressive in the future. Although such advances are now restrained by a legitimate concern for food and environmental safety, it is expected that in the not so distant future biotechnology could benefit not only agricultural producers but also consumers, agrifood industries, and the environment. Applications of this tool could also have a critical and strategic value in the world of soils, where they could serve to “biologise” non-appropriable management methods, now strongly influenced by the use of inorganic inputs.

The growth and expansion of the biotechnology industry, focused on ‘appropriable’ technologies, could bring large and diverse benefits to the different actors in the agricultural environment. By its nature, this methodological tool could favour both an increase in the diversity and quality of crops adaptable to the marginal conditions prevailing in subsistence agriculture, as well as the monopolistic concentration of food production and processing systems in commercial agriculture. The importance of this later trend will depend on the institutional and economic environment within which the technologies are developed and applied. But so far biotechnology seems to have a relatively modest impact, if any, in most developing countries, especially upon technologies aimed at smallholders cultivating marginal lands. Its increasingly private nature and the smallholders’ low capital availability appears to be discouraging labs to address their problems and inhibiting poor farmers to get their new products.

Information and Communication Technologies (ICT) have already played an important role in promoting agricultural development. Latest developments in this field are having significant impacts on the way agricultural knowledge is generated and transferred. ICTs are based on the amalgamation of three technological sectors: i) telecommunications; ii) computerised information processing; and iii) data and image transfer. They have the potential to:
- Facilitate the interaction among actors from different sectors in social processes leading to the generation and dissemination of technologies, through their active participation in innovation networks;
- Improve decision making regarding natural resources use through the development of GIS-based (Geographic Information System) capabilities to relate information from different geographical scales to systematise agricultural land use, and to facilitate the analysis of relationships between local and global priorities;
- Facilitate the efficient management of, and the design of appropriate policies for diverse, complex and uncertain land systems, through the design of knowledge-based decision support systems (KB-DSS),
- Improve the precision of agricultural practices guided by Geographic Position Systems (GPS); especially for the application of inputs to large and heterogeneous tracts of land (increasing its bioeconomic efficiency, and decreasing the environmental impact of the ‘high-input’ agriculture).

Given all of these applications, ICTs have a large potential to increase economic expansion, provided that they are accessible to all actors along the food systems. Trends in technical change based on ICTs tend to increase labour demand for people with higher education and skills, leading to income inequalities already visible in some developed and developing countries. To prevent such undesirable effects, this technological opportunity requires even greater emphasis on the strengthening of educational efforts aimed at the poorest sectors of the population.

An increasing concern for the conservation of non-renewable natural resources is gradually taking the agronomic sciences to incorporate the three main characteristics of ecological systems into the management of agricultural lands: biodiversity, ecosystem functions, and spatial heterogeneity. Such an emerging trend follows the recognition that an ecological approach to agriculture, or ‘agroecology’, is important for the development of sustainable agriculture. First, because diversity in the genetic resources of plants, animals and soils biota is essential to develop the appropriate biological components required by different agricultural production needs. Second, because functional relationships between availability of energy and materials and crop requirements are also fundamental to the sustainable efficiency of production systems; and such relationships are maintained and limited by the type and performance of species and populations present in the landscape. And finally, because this spatial area where organisms and relationships interact is never uniform, and an ecological approach helps farmers to manage the heterogeneity of gradients, patchworks and gradients of patchworks in the landscape, rather than to force the development of homogeneous domains.

2.7 Changes in the role of the Public Sector and Civil Society

In the last two decades most developing countries embarked themselves in profound programmes of economic and fiscal reform. On the whole these reforms were urgently needed to correct an excessive government intervention in the economy, and an
extended bureaucracy that had grown inefficient. In many cases, however, the
unintended result has been a weakened public sector incapable of providing necessary
public goods. Public investments in agriculture in general, and agricultural research in
particular, suffered sharp declines in most developing countries, significantly changing
the context for rural development efforts.

After a long period of expansion and consolidation NARS in many countries,
mostly of Latin America and Africa, have been confronting increasing difficulties to
access the resources needed to sustain their level of operation and, in some cases, are
experiencing the erosion of their capacities to provide for the technological needs of
their clientele, setting the stage for a vicious circle of reduced budgets limiting the
capacities of the research centres to operate, which in turn leads to an image of lack of
effectivity and a weakening of the political support needed to successfully compete for
the ever more scarce public resources. The political environment prevalent in the 1960s
and 1970s, in which public investments in research were seen as an unchallenged
necessary component for any successful rural development policy, has been replaced, in
many situations with one in which the legitimacy of NARS claims for public resources
is under serious questioning. This is taking place in a context where a number of
developed countries, including the United Kingdom, New Zealand and Australia,
among others, have also set in motion profound reorganisation processes of their public
research infrastructures to make them more responsive to market forces, implying, in
cases, the complete privatisation of the existing capacities.

These reorganisations are in part a response to the growing investment by the
private sector in most developed countries which are now making a significant
contribution to the development of embodied technologies. For example the period
1981 to 1993 private investment in Agricultural Research increased in the OECD
countries by 5% annually. This process has not replicated with the same intensity in
developing countries thus contributing to the relative weakness of research and
development activities. The problem is not only one of investment in agricultural
research. The new scientific developments in biology information, technology and the
growing importance of the private sector in the innovation process will lead to profound
institutional transformation in the public sector.

A second important change is the growing importance of non for profit private
organizations in activities related to natural resources conservation adaptation and
application of agricultural technologies and work with rural poor. These organizations
are an important institutional resources in a strategy for the development of Agriculture.

3. Impacts of Global Trends on Agriculture

The above trends in food demand, agricultural production and the environment,
science and technology, and the role of the public sector could affect agricultural
development in ways that outgrow their growth benefits. Thus:
The discussion of whether, or not, food production will be enough for feeding an ever increasing population has been going on for decades. In recent times some extensive econometric trend analysis covering the last fifty year seem to lend support to an optimistic view about the possibilities of meeting future world food needs; the problem being not so much food availability as having the income to access the food supply. Other analysts, however, are placing the warning that the world could be rapidly approaching its agricultural carrying capacity. Such differences are based on methodological perspectives, stemming from the recognition, or not, of inherent ecological limits to production growth.

Econometric approaches to production estimates are shaped by exponential growth curves of yields over time, resulting from projected growth of historical rates derived from continuing technological advances and investments in agriculture. Approaches influenced by the concept of carrying capacity suggest a logistic path with upper limits imposed by ecological stresses. Against this background, a recent analysis of global cereal production since 1961 shows that yield growth rates in developed nations have slowed down, with a trend to plateau in a fluctuating pattern since the mid-80s; but yields in developing nations have grown steadily over the full period (Fig. 8) suggesting that developing countries are on the lower portion of a logistic curve, while developed have reached the higher (estimated as a 5-year lead time). Logistic patterns are more clearly seen in yield growth records for the two major cereal crops, strengthening the hypothesis that yields in developed nations are reaching the upper limits, while those of developing countries leave considerable margin for further growth (Figs. 9 and 10). Consequently, if the logistic growth model perspective is accepted, developing countries may soon start to experience the slowing of growth rates which is already apparent in developed countries agriculture. Under these conditions production in developed country should double by 2025, just enough to meet the projected needs of the developing world at that time, a different projection from that given by most econometric models.

In this context the critical question is if existing systems of food supply can both keep up with overall food demand, which will continue to grow during the next decades, and make it accessible to all people around the world. The intrincacies and implicit contradictions that make up the supply-demand component of the food security situation have been clearly summarised in a recent report: "... the world food situation at the threshold of the 21st Century is mixed: astonishing advances in agricultural productivity and human ingenuity have not yet translated into a world free of hunger and malnutrition. Dramatic changes in food production, processing, and trade in recent decades have resulted in enough food to meet the basic needs of each and every person in the world. Doubling grain production and tripling livestock productions since the early 1960’s have made available about 2,700 calories per person per day. Yet, about 820 million people lack access to sufficient food to lead healthy and productive lives, and about 160 million children are seriously underweight for their age. This mixed
outlook for the world food situation gets significantly worse when one looks at the deterioration of key production components of food security, such as water availability, land quality, human resource development, and the capital-intensive bias of technological innovations.”

3.2. On Production Efficiency

Data from lands where high-input agriculture is in full swing (USA, EU and Japan) indicate that production in this systems is ‘profitable’ due to government subsidies, as without them it would not be competitive. This negative impact on the competitiveness of agriculture is based on the time-decreasing response curves to agrochemicals, both in terms of yield and pest and disease incidence, and the consequent greater use of inputs, which amounted to a 426% increase for fertilisers and pesticides from the 50s to the 80s. This technological path, represented higher production costs - about 50% for the USA during the period in question - which lead to a 20% decrease in net income, in spite of an increase in gross income.

In this countries higher primary productions are the result, therefore, of decreasing responses to greater external inputs; that is, they are based on ‘throughput’ and not on higher bioeconomic efficiencies. In other words, ‘getting more with more’. It should be noted that, in addition to this inefficient production, distribution and marketing in modern food systems are estimated to take 90% of the total energetic costs (i.e., 9 times the energy taken for production). The desirability of shifting great quantities of food around the world, compared with more local and regional production, needs then to be considered.

Trade globalisation and a greater exposure of the local agricultural economies to international competition is opening the possibility of reducing, if not eliminating, this inefficiencies through changes in the regional localisation of commercial agricultural production. This could lead to move primary production away from subsidised economies to developing countries, benefiting both consumers around the globe and competitive producers in developing countries; while in developed countries it would allow lands used for agricultural purposes to be shifted to the increasingly demanded ‘environmental services’.

This potential efficiency gains are highlighted in a recent comparison between energetic efficiencies of grain crops grown under high and low inputs in Bangladesh, Colombia, China, Philippines, USA and UK, which show that, on the average, those under low inputs are almost five times greater (1.34 kg/MJ) than those under high inputs (0.28 kg/MJ). In the Philippines it has been estimated that moving from the traditional to the modern system of rice production implied an increase of 3000% in energy inputs, to get a 116% increase in yield (a 26:1 ratio).

In spite of this generally positive impacts, relocation could have differential impacts within specific countries, depending on the capacity of different groups of farmers to access capital intensive technologies and the size to "link" into agroindustrial
chains and/or to achieve the economies of scale requires to compete in an economic environment on increasingly lower prices.

3.3. On Poverty and Equity

3.3.1 On People’s Wellbeing

High input agriculture has been the main force behind the 150% reduction in the price of cereals and other food staples that has taken place over the last two decades, which made possible a reduction in the incidence of poverty from the estimated 50% of total population in the 60s to the present 24% (estimated as people below the $ 1/day). The effects of increased agricultural productivity and production and the lower prices benefited mainly the urban poor, but has not had the same effect on rural areas, where overall poverty has remained at very high relative levels, in many cases more than 50% of total poverty. The most affected regions are Sub-Saharan Africa, where poverty levels remain at the same level of the 70s, and South Asia, where poverty moves between 40 and 45% of total population. Although levels are lower (16%), poverty in Latin America's rural areas does not show sign of abating either; where rural areas house a relatively high proportions of the extreme poverty cases occurring in the continent.

In this context, recent estimates show that between 1990-92 and 1994-96 the total number of undernourished people rose from 820 to 827 million, as a result of increases in three out of five developing regions in the world (Table 1).

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<th>Years</th>
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In addition to the number of hungry people, it is also relevant to look at the proportion of the population affected on a national and regional basis (Fig. 11). Overall, more than a quarter of the world’s hungry people live in countries where the prevalence of undernourishment is very high (35% or more). More than 40% of people living in Central, East and Southern Africa are undernourished. In Asian countries hungry people are equally divided between those living in countries with a 5-19% incidence and those with 20-34% category; while in Latin America and the Caribbean most countries fall in the 5-19%.
A special dimension of undernourishment is the proportion of children suffering from undernutrition, given its impact on human capital development. Estimates indicate that a very high proportion of children in the developing world suffer from undernutrition, resulting from a combination of inadequate food intake and diseases that hinder the proper utilisation of food. As it can be seen in Table 2, South Asia accounts for almost half of the world’s underweight and stunted children.

### Table 2: Undernourished Children in Developing Countries

<table>
<thead>
<tr>
<th>Degree</th>
<th>Regions</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-S Africa</td>
<td>NE&amp;N-Af</td>
</tr>
<tr>
<td>Stunting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Wasting</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

Poverty and undernourishment are certainly not the responsibility of agriculture alone. They stem, to a large extent, from deficiencies of an institutional nature (high levels of agricultural subsidies in the OECD countries, unsecured property rights, erosion of the culture related to the communal management of land resources, etc.). However, increases in overall food production serve to highlight the difficulties that exist to integrate marginal areas - where most of the poor rural people live - into high input/modern agricultural strategies, and to reach the smallholders that eke out a living from them.

### 3.3.2 On the Industrial Organisation of Agriculture and Equity

The industrial organisation of agriculture is changing both in its vertical and horizontal dimensions. Vertically there is a dramatic differentiation between what farmers produce and what consumers demand. While agricultural production is about raw materials, consumers demand food; from their point of view the product is not only the raw materials but also its processing, packaging and presentation, its availability in space and time, accompanying nutritional information, etc. An increasing proportion of the today's food supply is the result of long chains of value adding, usually the result of chemical and industrial processes undertaken beyond the farm gates, and where the farmers share in decision making as well as in the proportion of the final price is ever
smaller; in many, if not most situations, farmers are becoming de facto dependent contractors of the processing and distribution agents having surrendered to them their product and farming system choices. In modern agriculture, the balance of decision making power, as well as the larger share of profits, is no longer with the farmer but with the non-farm components of the food chain. In the 1950’s in the US, farms and their suppliers accounted for 57% of the value added in the food chain and the entire set of downstream food processing and distribution industries represented 43%, today the share of the final food bill captured by farmers and their suppliers is only 22%.

While, probably, the above figures represent the upper boundary of the extend of the restructuring that is taking place, the tendency is representative of what is happening in most of the developed and developing world, and it clearly emphasises that the survival of rural communities is no longer dependent upon farming efficiency but on their capacity to attract no-farm agro-industry and food industry investments, which not only have a higher share of the value added but also higher employment requirements than primary sector production.

Even though it seems beyond argument that the development of agroindustrial “chains” brings about both greater access by producers to world food markets, and lower prices to urban dwellers - resulting from reduction in transaction costs along the chain through ‘vertical’ structures and/or contractual arrangements-, the process is not without costs. Besides the already mentioned loss decision making power, these developments seem focus, in a few products, essentially on resource-rich environments, adopting input-intensive production systems oriented to get more (production) with more (inputs), supported by ‘patentable’ high-yielding technologies. These production strategies are also usually associated with a decreasing biological efficiency of industrial inputs.

These tendencies are accompanied by an also increasing level of horizontal concentration in the different market levels of the food system, including farming where in most of the agricultural economies there is a secular tendency to the reduction of the number of farms and an increase in their average size and production level. It has been estimated that for the year 2000 the number of farms in the US will be around 75000, down from an estimated 180000 in 1982, and 50000 will be responsible for about 75% of the AgGDP; similarly it is estimated that in Argentina during the last decade (1990-2000) the average farm size in the Pampean region -the richest in the country- grew in almost 20%.

Concentration is also increasing in the input supply industry, with a few large multinational corporations gaining control of ever larger shares of the supply of strategic inputs such as fertilisers, agrochemicals and seeds, and in the transformation and distribution systems, including both the international commodity trade as well as local food distribution. At the international trade level the five largest commodity trading companies control about 75% of the grains market, and the tendency is also present in other more specialised sectors such as fruits and vegetables: in Costa Rica one company controls more than 50% of the total vegetable business, and the first three firms represent almost 70% of the total; similarly in Honduras, the largest firm accounts
for 40% of production, while the first three firms represent close to 80% of the total business. At the local distribution level, in some countries, such as France, Germany and the United Kingdom, the top five retailing chains control more than 50% of all food retail sales and a similar tendency is being reported for countries throughout the developing world, as the large US and European super and hypermarkets chains have entered their local markets through very active processes of direct investments and acquisitions of local food distributors; in countries such as Argentina, Mexico, Brazil and Costa Rica concentration indexes at the retail level are not far from those of the European countries and the US. In summary decision making power in the agricultural and food systems is growing away from the farm and the farmers and becoming increasingly concentrated in the hands of relatively few large agroindustrial and commercial global players.

3.4. On Environmental Conservation

Agriculture and natural resources have been always intimately related. Moreover in a broad sense agricultural activities, could be defined as the premeditated perturbation of natural ecosystems for the purpose of food and fibre production, and every perturbation is in its essence an alteration of pre-existent equilibrium. Ever since mankind started to multiply and diffuse species to attend its needs, a large part of the planet resources, essentially soils, water and plant and animal germplasm, has been subject to invasive procedures, which, in many cases, led to the irreversible deterioration of their productive capacities. It is evident that the technological path implicit in high input agriculture, while making a significant contribution to the solution of food availability, has been taking many non-renewable natural resources into the danger area, either ‘polluting’ the environment through the inefficient application of agrochemicals in high-input systems, or by ‘degrading’ land through the mining of soils in subsistence systems where heavy land pressures prevail.

3.4.1. On Land Pollution and Human Health

The impact of pesticides on the health of rural population is increasing, especially in developing countries where safety measures are not properly followed. In the last decades agrochemical inputs have increased considerably, estimated now at $21 billion and a fourth of them are insecticides. Among the developed countries the largest user is the USA (27%), Western Europe (30%), and Japan (14%), leading to the contamination of underground waters above the safe limits (more than 50% of the sources in Spain, The Netherlands and Italy). Use in the developing countries is increasing exponentially, expecting to reach by the year 2000 close to 40% of the total agrochemical used in the world (while it decreases in developed countries, due to stricter controls).

Two studies on the costs of pesticide use in US agriculture put the total external cost at between 1.3 and 8 US billion/year, including those for public health damage, loss of natural enemies, pesticide resistance, reduced pollination, groundwater contamination, etc. A survey on human impact of pesticide-related health problems of farmers in four Central America countries producing non-traditional agricultural exports
Agriculture in the Early XXI Century

(NTAE) indicates that the incidence of illnesses is high (between 28.4 and 57.8%). The increasing evidence of long-term effects linked to pesticide use is sufficient to further the concern over health hazards faced by producers, labourers, and the rural population.

3.4.2. On Land Degradation

Considering land not only as soils, but as the integration of different ecosystem components (water, vegetation, landscape and micro-climate), its degradation refers to a decline in productivity at fixed levels of external inputs. Degradation is a more difficult impact to assess, given technical difficulties, the lack of databases, and the still weak predictive relationships between land degradation and agricultural production. There is, however, widespread agreement that the pace of degradation processes has increased during the last decades, and, in many cases, is reaching levels which definitely put in danger not only the continuity of production in specific situations, but are also starting to affect wider ecological functions. Box nº 1 presents a list of indicators highlighting the extent of degradation of different categories of land resources.

Box nº 1: Extent of Land Degradation Processes

Nearly 2 billion ha of potential agricultural land (i.e., cropland, pastures, forests) out of a total of 8.7 billion ha (22.5% has been degraded since World War II (Fig. 12);
- Of the 22.5%, degradation in 3.5% is economically irreversible, 10.5% has been moderately degraded, and 9% lightly so;
- Of the total potential agricultural land area
  - Almost half of the is under forest, of which about 18% is degraded;
  - 3.2 billion ha are under pasture, of which 21% has been degraded; and
  - 1.5 billion are under crops, of which 37% has been degraded (Fig. 8);
  - Chemical degradation due to cropping practices (e.g., salinisation and nutrient loss) account for a smaller overall proportion of degraded lands, but more than 40% of croplands degradation.
- Of global drylands:
  - 89% are rangelands, of which 73% is degraded;
  - 8% is rainfed croplands, of which 47% is degraded;
  - 3% is irrigated croplands, of which 30% is degraded.
- Different sources suggest that the world is losing 5-12 million ha annually to severe degradation, a trend that would lead to a loss of 1.4-2.8% of total agricultural, pasture and forest land by 2020;
- Comparing degradation in the different developing regions shows that:
  - Degradation of croplands appears to be most extensive in Africa (65%), compared to Latin America (51%), and Asia (38%);
  - Pasture degradation seems to be most extensive in Africa (31%), compared to 20% in Asia and 14% in Latin America; and
  - Forest degradation is most extensive in Asia (27%), followed by Africa (19%) and Latin America (14%).

From an agricultural perspective, soil degradation appears as one of the most important issues. The direct costs of soil erosion, as measured by the cost of replacing water and nutrients on agricultural land, have been estimated as U$S 250 billion/year globally. In spite of the uncertainty about the magnitude of such costs, it seems that the benefits of many prevention measures may well outweigh the high costs of soil erosion. Declining soil fertility is a major problem in low-income countries, where low capital availability leads to a “mining” approach to agriculture. Estimates show that 86% of the
countries in Africa have negative balances of nutrients larger than 30 kg. Of NPK/ha/year. Current average consumption that a larger use of fertilizers will be needed to improve soil fertility. The issue is "how" it is applied, so that it can be "trapped" to ensure a maximum efficiency in its utilization.

Beyond their function as factors of production, non-renewable natural resources provide ‘life support services’ at virtually every scale. Many of these services are free of charge (not captured by markets), and not yet substitutable by technologies. Land degradation associated to the agricultural intensification process, is already affecting species and cycles, with the resulting decline in ecosystem services. Although services are usually associated with remarkable species doing particular ‘jobs’ (e.g., trees, bees, bacteria, or whales), ecosystems not only contain such species, but also myriad of less well-known species present in biotic support systems; as well as the abiotic components of their habitat. Ecosystem services which are being put at risk by land degradation, include, among others: (i) the conservation of biodiversity - to maintain populations of species(e.g., bacteria, trees, crop varieties) at levels required to reduce risk and increase the agroecosystems resilience; (ii) the regulation of exogenous chemical or physical inputs, associated with the ‘filtering role’ of whole ecosystems, rather than with particular species; such as cycles of chemical compounds (e.g., water, N, CO2), regenerating soil fertility; (iii) the detoxication and decomposition of wastes; (iv) the organisation of biotic entities conferring adaptability to ecosystems (from gene sequences to networks of energy and material flows), as a basis for their resilience against a certain degree of natural and human induced disturbance).

3.4.3 On Water Availability

Of the total water on the earth only 2.5% is not salty, and just 0.08% is actually available for human use (the rest being either trapped in ice-caps and glaciers, unaccessible, or in the forms of monsoons and floods). Of that 0.08% about 70% is used in agriculture, and the remaining in households and industry. Groundwater is an important component of that 70%, as 10% of the world’s agricultural food production is based on its use. But water tables are falling as much as a meter/year in many parts of China, India, Mexico and elsewhere, following the ‘mining’ of acquifers at unprecedented rates. Moreover, water diversions for irrigation are causing negative environmental impacts in Central Asia, and industrial agriculture is markedly affecting the quality of water in rivers and lakes of capital-intensive agricultural areas. The quantity and quality of water available is then a major concern for the future, as it could become a limiting factor for agricultural development in the XXIst century.

In this context, a recent analysis of global water supply looks at the impact of its availability on agriculture. On the demand side conservative estimates indicate that by 2025 demand for irrigation water will increase in 17%, assuming a 30% increase in irrigated lands in a 'business as usual’ approach. Should expansion of irrigated lands be limited to 5-10%, not, production pressures to meet growing food demands would then be diverted onto rainfed lands, with the consequent impact on land degradation.

1 Following industrial agriculture, in the USA 71% of the maize area is planted to 6 varieties, 96% of the pea area to 2 varieties, 65% of the rice area to 4 varieties; and 76% of snap bean area to 3 varieties.
On the other hand, a ‘technical business’ approach based on the full-cost pricing of all water services (focused on heavy investments in dams, desalination and wastewater treatment) could moderate increases in demand, but at the risk of solving global water problems at high social costs in many developing regions. It appears then that increasing water withdrawals may impose unbearable stresses on the environment, to the level that ecosystems might not be able to cope with both human and agricultural demands. To achieve a sustainable balance between water supply and demand may well require of institutional and behavioural changes; but it will also require for agricultural technologies to adapt to the conditions of a water-scarce world.

In principle, three appear as the main ways through which agricultural technologies could contribute to a more efficient use of water: biotechnology, precision farming and soil water management. Biotechnology can help by harnessing the power of knowledge about genes and the new tools to create plants more resistant to drought and salinity, but above all with a more efficient water metabolism (“more crop per drop”). By integrating evapotranspiration requirements, ‘in-time’ and ‘where-needed’ applications of water and fertilizers, and drip technology, so-called ‘precision-farming’ techniques could also improve substantively the efficiency of water use.

The amount of available water stored in the soil profile is critical for an efficient utilization of agricultural water, and it depends upon the water holding capacity of the soil and the partition between infiltration and runoff. The former depends in turn upon soil organic matter, which makes soil structure more porous and stable. As organic matter contents are associated to the level and activity of the soil biological population, a healthy soil is valuable in holding water and making it available to plants ‘as needed’. The way in which different intercropped species divide the limited available water supply may also be beneficial to a more efficient water use, as well as their root penetration - so that the profile can be dried out at different depths.

Finally, an integrated approach to the management of water resources appears as a ‘soft’ technology essential to develop a technically efficient and socially acceptable scheme. A participatory process of decision-making made at the lowest appropriate level in the framework of a basin, catchment or aquifer seems to be the natural unit where interested actors can recognise their common interests and collectively negotiate the private and social costs/benefits derived from their activities.

3.5 On the Dynamics of Research and Development Systems

Research and development systems are evolving in a complex manner both in terms of the structure of the markets for technological knowledge as well as in the way the agricultural research and development process is organised.

With the development of more capital-intensive, high-input agriculture, commercial farmers tend to rely on outside suppliers to provide their agrochemical, seeds and feed stuffs. Most of these suppliers are aiming at a world market, and taking a global view of their business. In this context, agrochemical industries are
consolidating through mergers and buy-outs, a process started 30 to 40 years ago, and are now branching into seed production, including genetic engineering. This diversification is in part a result of their interest to produce pest-resistant plant and animal varieties on the one hand, and varieties tolerant to specific pesticides on the other.

The rapid development of biotechnology and ICTs as R&D tools, and the diffusion of intellectual property rights into the life sciences area, is having a significant impact on the institutional organisation of agricultural and natural resources research and technology development. Biotechnology has a scientific base significantly different from that of traditional agricultural research, demanding different disciplinary capabilities both in terms of the human resources involved as well as in the type of institutional links through which applied research organisations access the basic scientific knowledge needed for their work. At the same time, due to the intrinsic nature of technologies as well as a more comprehensive coverage of IPRs legislation, a relatively large proportion of the products of biotechnology are appropriable, setting the stage for a redefinition of public-private relations in technology development. This new environment represents, in many cases, new opportunities, as it provides the basis for additional resources flowing into agricultural R&D. However, it is also true that these increasing private linkages between science and technology development tend to result in the generation of technologies ‘built into’ goods, that cannot be easily adapted to the heterogeneous agro-ecological circumstances of developing countries. Public sector R&D could play here a key role in applying biotechnology to the small-scale, diversified and heterogeneous “problematique” of small farmer agriculture, not yet attractive for the private sector.

The new ICTs have a great potential effect on the effectiveness and the efficiency of resource use in research activities. The application of microelectronics to data management is drastically reducing the costs of doing research by improving the access to and the processing of information, but also by facilitating and making more efficient the development and operation of networking schemes. These could help research both within classical research organizations and in the participatory forms of research. The former by involving distant facilities to achieve a minimum critical mass in terms of human resources and specialised equipment facilities, while decentralising research to bring capabilities into direct contact with the problems in need of solution. Geographical information systems (GIS), global positioning systems (GPS), and remote sensing are also contributing to improve research efficiency by reducing the need for experimental replications and allowing a wider extrapolation of research results into homologous environments.

ICTs could also help participatory forms of research by giving community nodes the opportunity to both get information on climate, markets, new technologies, etc. and send information on agroecosystems health, new developments, etc. Such means of communication are starting to be available in commercial agriculture areas, but as the costs of alternative energy technologies (wind and solar) and cellular phones and internet access continue to fall, they will also be accessible for small farmers in the developing countries.
4. Reflections on trends and impacts: Fulfilling the Vision

The proposed vision is built on three elements: 1) food security, 2) poverty eradication and 3) a more sustainable use of natural resources. The vision is an abstract concept that defines the long term objectives. It is a moving target, difficult to obtain, that helps to identify and focus on the most important and effective areas of intervention.

The previous discussion suggests a general agreement that by the year 2025 aggregated agricultural production should be enough to meet the global market demand for food. The "green revolution" has been successful in bringing about the dramatic increases in agricultural production and productivity, and through that in assuring the availability of more and cheaper food, especially to satisfy the needs of the urban poor. But if in the coming decades we are to ensure that all poor people are well fed, there is the need to go beyond those achievements. We should undertake the challenge of increasing production in subsistence systems on lands with lower agricultural potential, where a high proportion of the rural poor live, while, at the same time, minimizing and, eventually, reversing the negative environmental impacts of high input agricultural paradigms associated with commercial agricultures supplying urban populations.

In other words to approximate the proposed vision we need to attain the following goals:
1. Maintain 2-3% annual increase in food production world wide to assure global food security.
2. Assure an adequate regional localization of production specially in food deficit regions. Given the projected levels of regional food gaps trade alone could not assure regional food security.
3. Develop technological options less dependent on chemical inputs and more environmentally sustainable.
4. Improve the productivity of marginal lands and poor farmers.
5. Contribute to development processes that lead to economic growth without excessive economic concentration, urbanization and equal distribution of incomes and wealth.

From the perspective of research and development institutions the challenge is both technological and institutional. There is the need of both technological strategies appropriate for the marginal areas where small holders are eking out a living and a common economic framework for agricultural production and resource uses, to integrate the traditional and commercial sectors. The new paradigm should provide the institutional and policy basis for:
- Reorienting research and technology development investments and activities to generate technological innovations that increase both the efficiency in the use of production capital (exogenous resources) in "commercial systems", while ameliorating pollution impacts of high-input technologies; and labor productivity in "subsistence systems" under low capital inputs while avoiding the "mining" of land resources;
Promoting stronger complementarities between the two agricultures” in supplying markets, and
Interactive participation of actors from different sectors within and between levels of social aggregation, to generate and disseminate information on costs and benefits of alternative land use systems leading to more sustainable resource use.

5.1 Technological Development Patterns

A recent analysis talks about two main types of agricultural systems vis-à-vis the development of technological patterns, determined mainly by the use of mechanical, biological or chemical inputs. The first is that of extensive systems, present in land-rich and labour-poor countries, e.g. North America, parts of South America, South Africa and Australia, and several countries in the ex-Soviet Union. The second refers to intensive systems, where the labour-land ratio is high, like in Europe, Japan, China, India, and many developing countries in Africa, Asia and Latin America.

In extensive systems the technological change towards the external input-based ‘open’ system was initiated through mechanisation, as a way to replace labour, the most scarce and expensive resource. The biological and chemical changes came into an already large-scale and mechanised agriculture. As a result, the original closed model was transformed into today’s highly mechanised and input-intensive open systems, with their corresponding production and environmental impacts.

In intensive systems the scale-neutral biological and chemical inputs preceded the mechanical ones. Agriculture is then still small-scale, but very intensive in the use of biological and chemical inputs, and highly specialised. In Europe, its impacts on food-safety and the environment are at the roots of the increasing civil-society’s concerns.

Whatever the scale of operations, prevailing technological patterns are leading commercial agriculture into high-input models with the consequent environmental impacts. Moreover, such capital-intensive models can not be applied to subsistence farming, forced to deplete the natural resource base. There is a need then to move into a new stage in the agricultural use of resources that combines the needed intensification of open systems with the sound ecological management of the closed ones. Such a ‘blended’ pattern should become the basis for technological developments facilitating:

- the sustainable intensification of subsistence agriculture in highly populated and heterogeneous low-resource areas;
- The conservation of the natural resource base in the resource-rich areas of commercial agriculture;
- a more diversified and multifunctional use of rural lands.
5.2. A Knowledge-driven Pattern

The extraordinary developments of science in recent years present new opportunities to address these technical and social shortcomings of the technological path that has dominated world agriculture in the last 30 years. They facilitate the development of Knowledge-Intensive Agricultures (K-IAs), i.e., a process for the integrated use of land resources based on both biophysical inter-relations in agro-ecological systems and full participation of land users in technology development. This K-IAs seek to:

- Technically increase production efficiency and natural resource conservation, applying biological and ecological knowledge to maximise the utilisation of endogenous processes, and to optimise the bio-economic efficiency and safety of exogenous inputs;
- Socially integrate all relevant actors in the process of technology development for the sustainable use of agricultural lands, applying communications and information technologies to facilitate an active interaction among them.

To make full use of the endogenous processes potential, K-IAs are based on a deep understanding of relevant ecosystem processes, which allows a careful adjustment of production practices to the uncertainty given by ever-changing conditions. The adjustment of production technologies to such changes in ecosystems requires of an adaptive management that can only be made by highly informed, observant and committed producers. K-IAs are then strongly based on the active participation of producers in the innovative process, making the development of Human Capital a major element of the strategy. Knowledge-intensive agricultural models should change the focus on input productivity of information-based ‘technological packages’ to that on bioeconomic efficiency of synergetic processes among endogenous natural resources, adapted crops, and external inputs. This opening of ‘black boxes’ in technological packages will allow farmers to ‘blend’ external information with their own, a process that should lead to the ‘social appropriation’ of resulting technologies.

5.3. Characteristics of Knowledge-Intensive Agricultures

In the GSV the GFAR visualises that an alternative agriculture should be equitative, profitable and competitive; while it should also conserve the natural resources, promote a community-centred rural development model, and be based on diversified production structures. K-IAs should then be flexible enough to strike a delicate balance among the multiple objectives of i) optimal use of available resources; ii) achieving economic (competitive), social (equitative) and environmental (conservation) goals; and iii) adjusting to changing economic and policy environments.

On the operational front K-IAs have to reconcile the potentially conflicting goals of productivity growth and natural resource conservation, by going beyond the conventional focus on farmers as producers of commodities, to examine both their behaviour as land users in an ecosystem context and the circumstances that shape that
behaviour. This expanded focus requires of K-IAs to view land user’s circumstances as a hierarchy of interconnected systems, expressed in particular patterns of resource utilisation across the rural landscape. K-IAs should then encompass agroecosystem activities developed at different geographic and social scales, where externalities of agricultural activities at a particular scale could have an off-farm impact on the use of resources at another scale. Costs and benefits of such ‘externalities’ need to be negotiated among relevant actors from the corresponding levels of social aggregation. Considering the socio-economic, technical, institutional and political dimensions of agriculture, K-IAs could then be characterised as having a Multifunctional Role; resulting from Pluralistic Participation; structured around Agrodiversity; built on Science; and governed through Decentralised Decision-Making.

5.3.1. The Socio-Economic Dimension

Contributing to food security through the production of food and other primary goods is still the most important role for K-IAs. In addition, agricultural activities and other land uses yield a wide range of non-food goods and services, a Multifunctional Role that can affect social and cultural systems and contribute to economic growth. Agricultural land uses are inter-related, and their relative importance will depend on strategic choices at the local and national levels. This notwithstanding, such land uses could be grouped according to their:

- economic functions, as a main force in sustaining the operation and growth of the whole economy, especially among developing countries;
- social functions, maintaining the dynamism of rural communities to improve the life quality of rural residents, and capitalising on local knowledge to develop sustainable innovations, and
- environmental functions that mitigate the impact of agriculture on natural ecosystems, by designing agro-ecosystems that optimise the beneficial linkages between agriculture and the ecological functions of the natural environment.

Compared with the specialised high-input agriculture, K-IAs are then more complex systems, requiring the management of a greater ecological and economic diversity. Under these circumstances information becomes a critical input for timely and multi-faceted decisions on the management of resources, which should be ‘internalised’ in synchrony with seasons, climate, labour availability, crop needs, pest cycles, etc. Moreover, managers must be able to anticipate outcomes, by ‘reading’ the agro-ecosystem ‘behaviour’ through appropriate indicators.

These knowledge and skills associated with K-IAs require the active involvement of managers in the acquisition, generation, classification and consequent appropriation of knowledge; processes that occur in the specific cultural, agro-ecological, socio-political and economic contexts in which they operate. But individual farmers are not the only actors in the development of K-IAs, as the balance between private benefits and social costs requires the full participation and collective action of all local actors, K-IAs innovations should then be the result of complex social processes driven by a Pluralistic Participation, that leads to deliberate changes in the management of natural resources,
influenced by the private and collective intentions of interested actors. This requires for innovations to be developed at social levels of aggregation congruent with the rural space of the problem or opportunity on hand; in a framework where actors can perceive a common reality; recognize that it makes them interdependent; design processes for decision-making and conflict resolution; and organize themselves to operationalize the management of resources.

The Regional Consortia for Agricultural Experimentation (CREAs) developed among commercial farms in the Southern Cone of Latin America in the 70s, and the Committees for Local Agricultural Research created by small farmers in the early 90s in northern Latin America (CIALs), meet these characteristics. They are constituted by farmers who try alternatives to address problems/opportunities identified through joint efforts with NARS technical staff. Results are then analysed and disseminated among community members and other Committees. This allows farmers to generate, through their own means and with their own resources, technologies appropriate to their own agro-ecological and socio-economic circumstances.

These social processes require changes in methods for the development of human resources, which should move from an emphasis on the ‘what’ to do, to the analysis of organisational forms through which farmers learn ‘how’ the ‘whats’ are generated and ‘with whom’ innovations ought to be negotiated. It is these social processes what should be ‘sustainable’ in developing K-IA, and not just the information-based technologies.

5.3.2. The Technical Dimension

Modern agriculture seeks to simplify agroecosystem structures to maximise production of goods that satisfy humans needs. Monoculture management with genetically uniform stock represents the extreme of this strategy. On the other hand, trends discussed under Science and Technology (2.6) indicate an increasing recognition of the key role played by biodiversity and heterogeneity in the conservation of agroecosystems (called ‘agrodiversity’, as given by species composition and/or agroecosystem structures in spatial and/or temporal arrangements). Such a recognition is based on the role of Agrodiversity in fulfilling agroecosystems functions fundamental to achieve a productive, efficient and sustainable K-IA. From an agricultural perspective such functions are essentially centred the role of two elements: soils and water. They include, inter alia:

- Regulating the sedimentary cycle, including the processes of physical and chemical erosion and sediment formation, for which water flows are mostly responsible.
- Buffering and moderating the hydrological cycle, to increase infiltration and reduce runoff, which are closely correlated with the loss of soils organic matter, making soils more prone to erosion and reducing their water holding capacity.
- Maintaining soils exchange capacity, holding nutrients in the proximity of roots to allow their gradual uptake by plant roots, crucial to regulating soil fertility including an efficient utilisation of inorganic inputs.
• Disposing of wastes and dead organic matter, which remains are recycled by soil organisms to other uses, and in the process rendering harmless many potential pathogens (soil organisms produce potent antibiotic compounds, such as penicillin and streptomycin).

• Renewing soil fertility through the processing by soil organisms of dead organic matter and waste, replenishing the nutrients required for primary production, and thus fuelling the life cycle.

• Controlling pests through natural predators, parasites and pathogens, to maintain the stability of agricultural systems and ameliorate agricultural ‘externalities’.

In addition to their impact on agriculture, the growing pressure on the land is also leading to an accelerating decrease in the proportion and variety of natural ecosystems fulfilling other environmental services. Given the structural simplicity of monocropping, agroecosystems are increasingly less capable of substituting for natural ecosystems in providing such services. Albeit partially, this could be achieved, however, by more complex KA systems with multiple functions of economic and environmental value. This hypothesis seems to be confirmed by a recent analysis comparing Swedish agriculture during a low intensity period (1950s) and a high one (1990s); which shows the loss of some ecosystem services in the latter as compared to those provided by the former.

Agrodiversity appears then as a necessary condition for the full development of K-IAs, a condition that could be built through technological innovations Based on the Use of Science for the Sustainable Management of Natural Resources at different scales in the agroecosystem. At the farm level K-IAs should develop sets of interdependent technologies oriented to the efficient and sustainable exploitation of the natural resources, through processes that promote synergetic relationships among components of production systems, e.g. i) direct sowing and cover crops, to protect soil surface by increasing organic matter content, maintaining the biomass and improving soil’s biological activities; and ii) crop-livestock interactions and legume rotations, to improve the flow and recycling of nutrients.

At the watershed level K-IAs should be the result of a combination of land uses across the landscape. As mentioned, species-rich agro-ecosystems have greater resistance to pests and diseases and resilience to external disturbances, which lower the risk of failure. But it is also known that the yield of annual species (in mass units/land/time) is normally much larger than that of perennials. Therefore, it could be envisaged that K-IAs may lead to the development of more complex agroecosystem structures, where in many cases high yield monocropping systems alternate spatially/temporally with forest/pastures, resulting in more productive, efficient and sustainable agricultural land uses.

5.3.3 The Institutional Dimension

From an institutional perspective, a change towards K-IAs requires of both policy instruments and organizational frameworks. It has been suggested that the process of institutional change starts with changes in the way actors perceive the
economic reality, followed by those in the beliefs about the economic model, and, finally, by changes in institutional structures so as to organise them in a manner consistent with new realities and beliefs. Against this background, global developments in the production dimension of agriculture - especially of the commercial type, but also in subsistence systems - indicate that institutional changes towards a market economy have passed the reality and belief stages, and are already in the second phase of the organizational one. In the conservation dimension, however, actors are just into the perception stage, beginning to recognise that life quality and long-term productivity are closely linked to the ecological integrity of agroecosystems. Given the “externalities” of agriculture on the productivity and environmental functions of natural resources, and the public nature of such functions, the process of institutional change towards K-IAs requires of: (i) democratic organizational mechanisms, that facilitate the participation of all interested parties in decisions influencing the social benefits and costs of agricultural intensification; and (ii) policy instruments that incorporate into markets the costs impinged by unsustainable management decisions upon the production and environmental functions of land.

Institutional Functions. As mentioned before, land production and environmental functions are affected by management decisions at both farm and regional levels. One of the main roles of institutions for the development of K-IAs is then to compatibilize the private interests prevailing when production technologies are selected at the plot level, with the public rationality that should guide the environmentally-minded use of lands at the watershed level. Under this circumstances, the main contribution of institutions to K-IAs would then focus on the reduction the transaction costs in negotiations among actors operating at different levels in the agroecosystem; essentially between those using lands for agricultural production and those affected by externalities resulting from the use of natural resources. Such negotiations are mainly influenced by the uncertainties about the actual impact of degradation on the production and environmental functions of natural resources; uncertainties that weaken the influence of laws and regulations seeking to compatibilize private and public interests. Organizational arrangements can contribute to counterbalance existing uncertainties by gathering and disseminating information on benefits and costs of alternative land managements at different hierarchical levels in the agroecosystem.

Organizational Arrangements. The complex interrelationships among hierarchical levels in an agroecosystem needs of organizational structures that articulate the impacts of different land uses on its ecological integrity with the bioeconomic efficiency of land management practices. Given the socio-economic, and even agroecological, heterogeneities among locations within agroecosystems, decentralising decision-making to the micro and macro-watershed levels of social aggregation appears as an appropriate structure to facilitate the development of K-IAs within agroecosystems. Such a structure would be aimed at the development of technological innovations, promoting: i) the appropriation by relevant actors of information and the sharing of rules for the sustainable use of natural resources; ii) their monitoring of actual land uses at their level; and iii) the systematisation of local knowledge into information systems. In addition, mechanisms at the micro- and macro-watershed levels will complement each other:
Those having the ‘micro-watershed’ as operating theatre facilitate a closer interaction between the environmental and productive components of K-IAs in the identification of technological demands. Opportunities for production diversification and for reciprocities among actors create a favourable environment for negotiations around alternative managements to mitigate ‘externalities’, where local authorities play an ‘honest broker’ role.

Those at the ‘macro-watershed’ levels could contribute to:

- identifying and/or developing opportunities to add value to the agroecosystem’s primary products, for both commercial and subsistence systems;
- gathering and disseminating information referred to the complex agroecological relationships between production and conservation of natural resources; and
- evaluating the impact outside the agroecosystem of both land use and land management, to inform the public and private sectors, and civil society, about regional trade-offs between the production and environmental functions of natural resources.

Organizational Attributes. Organisations at both the micro and macro levels should preferably be:

- Mixed, including members from the public, private and social sectors;
- Interactive, focusing on using K-IAs to change the local environment in which they operate, while looking at the external environment as a source of ideas and opportunities;
- Participatory, engaging the public, private and social sectors in consensus-based processes of decision-making to address opportunities and problems identified by interested parties; and
- Incentive-driven, favouring the use of incentives over ‘controls’ to compatibilize production and environmental concerns.

These organizational structures addressing needs for technological innovations at the agroecosystem level would benefit from further R&D at an agroecological level, essentially aimed at generating scientific information on the complex eco-technological processes governing production and environmental functions of agroecosystems.

5.3.4 The Policy Dimension

The problem confronting the rural sector is not the role of the agricultural sector in the national and global economies; it is the deterioration of the rural space as a locus for the creation of social, cultural and economic value. The emphasis on industrialisation as the basis for economic development and of the urban environment as the basic model for the settlement of population has redirected investments out of the rural areas an underestimated the value of natural resources and of rural areas themselves as an attractive place for the placement of non-agricultural economic activities. In many cases, this process left the new generations with no option but migration to the urban centres in search for opportunities for improving their livelihoods, and set the stage for the vicious circle between lack of opportunities, poverty and deteriorating living conditions and resource degradation, which needs to be reverted. Transition from existing practices towards a knowledge agriculture will
require the support of policies on agricultural development, knowledge and innovation systems, and institutional reform.

**Policies for Agricultural Rural Development.** Policies for revitalising rural economies require both a macro and a sectorial approach. At the macro level policies should be directed to:
- consolidate macroeconomic stability and a non distorting environment for agricultural production,
- appropriate incentives for technological adoption and natural resource conservation,
- consolidate the functioning of product and input markets,
- incorporate the natural capital into the national accounting system, to reflect its capacity to yield valuable goods and services into the future, fully integrating resource exploitation / conservation choices into the economic actor's decision processes, and
- promote the establishment of a wide range of functioning markets for environmental services.

At the micro level they should:
- establish credit incentives for innovation projects focussed at creating added value at the rural level, including both land management aspects and local agroindustrial processing,
- incentive the employment of local people in the implementation of those activities, and
- promote the integration of poor farmers into the markets.

**Policies to Support Knowledge and Innovation Systems.** Knowledge agriculture is diversity based, not only in resources, ecosystems and production systems, but also in its scientific base. Innovations systems for knowledge agriculture are multiple source systems, where technology is not "created" and "diffused" in a linear fashion, but is rather a co-evolutionary process where technology and innovation evolve in a incremental manner through the interaction of a wide diversity of actors, including scientific institutions, private sector organisations, NGOs and farmers themselves. Policies to support the consolidation of these systems need to focus on the management of diversity and the optimising resource use through co-ordination and complement. They should:
- prioritise research on natural resource processes in a watershed context, emphasising efficiency in resource use as well as full exploitation of the interactions between physical, biological and social and organizational science sources of innovation,
- create the conditions for full exploitation of the advances in the new biological, information and communications technologies,
- promote decentralisation of R&D organisations, to encourage the development of strategic alliances throughout the scientific landscape (national and international) and between public sector organisations and those of the private and the third sector, including community associations, and
promote and establish linkages between R&D and educational institutions to assure that human resources development is fully integrated to the needs of innovation processes.

**Institutional Reforms.** Institutions for knowledge agriculture should allow the direct participation of local actors in resource use decision making and, at the same time, integrate the diversity of environments into coherent regional and national strategies. Institutional reforms should be directed towards:

- decentralising natural resources management systems towards greater participation of local bodies, while establishing appropriate "multilevel" check and balances systems;
- incorporating information on the use of natural resources into policy decision making processes; and
- creating the incentives for individual decision making regarding resource use becomes convergent with socially desirable behaviours.

### 5.4 The Potential of Knowledge Agriculture

The validity of a knowledge agriculture will depend on its capacity to contribute to the central objectives of the GSV, that is, increasing food security, poverty eradication and the conservation and management of natural resources. High input agriculture was able, on its time, to fulfil its role with respect to these three objectives, specially when due recognition is made to the indirect positive effects that the phenomenal increases in food production have had on resource conservation by reducing the pressure on the less endowed environments. It is evident, however, that it has run its course as a valid strategy to organise agricultural production. The definitive available evidence on land and water resources pollution and degradation, and that major crops are rapidly reaching plateau yields, should be enough to highlight the need for an alternative concept. The question is whether, or not, KAs can meet the challenge, specially when considering that given food demand projections, resource conservation requirements can not be achieved through reducing agricultural production. The final answer to this, is, as always when working with vision concepts, an empirical one, which will be answered in time. But from a prospective perspective we think that there is solid ground to anticipate a positive response.

From a scientific and technological perspective it is clear that we are in the transition to a new technological paradigm in which the synergistic effects of the new biotechnologies, ICTs and alternative sources of energy will allow agricultural activity to shift to a new technological path where higher yield potentials are possible without incrementing external tangible and energy inputs.

On a more practical dimension there is already some evidence that even under the present technological environment, the task is possible. A recent IIED study of the productive potential of 1.82 million farms that are in transition towards a ‘sustainable’ agriculture (people-centred; diversified; and thriving on the use of natural processes
with a minimum of external resources), and covering 3.43 million hectares in more than 20 countries from the developing and developed world, lends clear support to this possibility. In the study farms were grouped according to their level of production (high, medium and low) at the start of the transition, about 10 years ago, and results show that production in farms coming from a high level of production decreased in 5% for wheat and sorghum-millet, remain at the same level in maize, and increased by 15% in rice; while farms coming from the medium and low levels, reported significant production increments, reaching 11% for rice (L&M), 120% (L) and 110% (M) for wheat, 120% (L) and 90% (M) for maize, and 165% (L&M) for sorghum and millet. Further evidence in the same direction results from the fact that in the USA the best 25% of farmers that apply ‘sustainable’ practices have larger gross margins than their peers in high-input agriculture.

Similar evidence is starting to be available for poverty and resource conservation issues. Records of high input agriculture on labour demand, including the ‘backward and forward linkages’, are, in general, very favourable. But they have been deteriorating rapidly (from a 40% rise in demand in the 60s to a 10% in the 80s), as the vertical integration of agro-industrial processes progress, and agriculture-related jobs tend to move to larger centres. On the other hand, the evenly-spread and labour-intensive nature of KAs should increase ‘local’ labour demand. A number of studies of European food systems have associated ‘sustainable’ forms of agriculture to strong rural development, highlighting that ‘in situ’ agro-industrialization is a good source of employment, contributing to local development and lower land pressure.

From the resource conservation perspective, there is clear evidence that arresting soil degradation through reduced tillage, diversification and rotation has benefited tens of thousands of rural families in an area of 10 million hectares in Brazil. The initial objectives of erosion control and sustainable land use evolved through a community-driven approach to an integrated way of managing natural resources in micro-catchment areas that increased agricultural production and the corresponding backward and forward linkages, stimulating non-agricultural rural activities. Long term results point to improved soil fertility, increases in the quantity and quality of water availability, and, eventually, lower production risks.

In a similar direction, the Rothamsted studies, run for over 150 years, show that wheat yields have averaged 3.45 tonnes per hectare on manured plots, compared with 3.40 for those receiving complete NPK fertiliser. But what is more important for this topic, soil OM and soil total N increased by more than 120% in the manured plots, but only about 20% in the NPK plots. Such Carbon stores might represent an under-appreciated sink for global carbon.

6. Towards a Global Research Agenda

The concept of a global research agenda is not new. In many ways the interrelated research efforts developed in close collaboration between the CGIAR
Centers and many national research institutions that led to the development of the green revolution was the result of the successful implementation of a global research agenda. What is new is the renewed and concerted effort developed through the Global Forum to construct in a systematic manner, a Global Research Agenda (GRA) concerted upon by all interested institutions through a widely participatory methodology.

In developing the GRA the lessons from past experience in the widely recognized success of the ‘green revolution’ must be internalized in the discussion. The major elements of world agricultural research were initially represented by the joint effort of the CGIAR and national research institutions of developing countries, and lately by Universities Third Sector institutions from the developing and developed world. Is that all? What are the ‘lessons from past experiences’? (secure resources?, focus?, decentralized organization?, excellent teams?, collaboration? what is it worth rescuing vis-a-vis the Global Forum?)

While previous efforts in global research were aimed essentially at increasing overall food production, present GRA endeavors seem to recognize the need to focus such continuing agricultural research on production increases leading to the eradication of poverty, the improvement of food security and the conservation of natural resources. In doing so it must be recognized that new boundaries and opportunities are being generated on every field of human activity, and some agriculture-based economic and social processes are among the most affected by the new developments described in previous sections. It is precisely this broad nature of the new research agenda, and the heterogeneous environment in which it has to be developed, that makes it even more attractive to concert efforts among interested partners around a common GRA, as a basis for interdependent actions around the development of international public goods.

The implementation of the GRA requires a concerted action in two inter-related areas of analysis: Research Areas and the institutional organization of a Global Research Agenda.

6.1. Areas of Research

The previously reviewed history of technology developments patterns (see 5.1) suggested the need to move into a new stage in the evolution of agricultural land use patterns. The new stage was described as one combining the intensification of “open” systems, to meet increasing food demands, with the sound ecological management of “closed” ones, to revert on-going land degradation and other negative environmental processes. It is expected that such a Knowledge Agriculture pattern should nurture technological developments supporting a diversified and multiple use of rural lands, and serving both the sustainable intensification of subsistence agriculture in heterogeneous low-resource areas and the conservation of lands in the resource-rich environments of commercial agriculture.

To accomplish these ambitious goals it is proposed that future KAs should include both biological and spatial ‘agrodiversity’ as a major technical feature and
‘pluralism’ as the principal socioeconomic trait, i.e., the full participation of and collective action by relevant actors in innovation development processes. These processes will then require information from the fields of agroecology and institutional economics, supported by biotechnological and ICT research tools.

As discussed before, one main element that needs to be introduced from the agroecological perspective into the new strategy is an increasing recognition of the need to integrate in agricultural management three fundamental aspects of ecological systems: agrodiversity, functional relationships among ecosystem components, and spatial heterogeneity. However, the development of KAs to their full potential requires not only technological but also institutional innovations. These should provide the incentives and institutional mechanisms that make viable the reorientation of production and distribution patterns towards a more sustainable and equitable resource use.

In this context, research efforts by public sector institutions in support of KAs should address all four areas. Although knowledge areas and themes are certainly not new, and may even look very similar to those pursued in previous patterns of technology development, it is the integrated nature of the approach and the foci which will make KAs’ research unique, and complementary to that developed by the private sector.

In the search for biodiversity, research on germplasm conservation could continue to cover the whole spectrum of agroecological zones including not only crop and animal species but also those in the soils biota. That on enhancement, however, should probably concentrate on crops produced by poor farmers and on low-resource areas, focusing biotechnological efforts on the adaptability of ‘below- and above-ground’ species to existing natural resources and socioeconomically feasible production systems.

In the area of functional relationships research to develop KA technologies should probably focus on crop productivity, through the improvement of soil fertility and the protection of plant health. Given the low capital availability in those areas, an important theme for soils fertility research appears to be the maintenance of soil organic matter and the role played by the quality of organic resources on patterns of nutrient availability, searching for relationships between cropping systems and functions of the soils biological community. Although aimed at resource-poor areas, knowledge on relationships between soils organic matter and nutrient availability is also necessary for an efficient utilization of exogenous inputs in crop production under capital intensive systems, and the corresponding amelioration of ‘externalities’ on other agroecosystem functions. Research on plant health should emphasize a practical understanding of the ecology and life cycle of major pests and their natural enemies, and that this knowledge be translated into appropriate decision-making tools and practical control tactics.

Research on spatial heterogeneity is of special interest for multidimensional decision-making on the sustainable use of agricultural lands. This requires that conservation concerns move beyond its current focus on production systems alone, to one that provides context for the interactions of such systems with other uses of the landscape. In this context, an important research theme are the key processes involved
in the up- and down-scaling of information linking agro-ecological phenomena across the hierarchy of agroecosystems, to identify the pros and cons of agricultural ‘externalities’ among different ‘patches’ in the landscape.

In the field of institutional economics, research should probably focus on the design of mechanisms to facilitate negotiations among actors about land uses and technological needs, and on environmental policies to promote the development of KAs.
6.2 The Global Research System

The implementation of such an agenda requires of a multi-institutional organizational framework, aimed at developing and taking advantage of a wide array of collaborative arrangements bringing together very diverse institutional partners. The research process for KAs needs to be loose ended, flexible and gradual, allowing for adjustments in scope and content as the research agenda itself evolves following changes in conditions and opportunities.

The discussion of this global framework needs to take into consideration some important developments that have taken place over the last decade. First, the increasing importance of research and technological development by the private sector, and how to bring its potentially enormous scientific and financial resources into the execution of the research agenda for KA. Its role is quite clear in relation to issues related to commercial agriculture, where the profit incentive can operate at its full potential. The challenge, however, is to find the institutional mechanism for attracting its efforts to the resolution of the technological problems of traditional agriculture and the less endowed environments. Second, the relative decrease in the allocation of public funding to agricultural research and its implications for the strength and productivity of many NARS of the developing world. Finally, globalisation and advances in information and communications technologies have dramatically changed the potential and the efficiency of mechanisms for the exchange of scientific information, greatly facilitating the generation of research partnerships.

Within this context the development of the Global Research System must be seen as a process of institutional development aimed at:
- the progressive strengthening of all individual institutions involved;
- a systematic learning process in relation to research collaboration, strategic alliances and partnerships; and
- setting up the institutional mechanisms and incentives for a growing level of participation of all institutions controlling resources of potential importance for achieving the system's objectives.

From the operational point of view, this process should lead to each institution concentrating in the areas where they have comparative advantages on the basis of their inherent capabilities and natural constituencies. Fig. 9 shows a way of "clustering" institutional organisations along the line relating research scope to the heterogeneity among institutional actors. The geographical scope of innovation networks at the local level is small (watershed), while the large number of interested institutional actors raises the level of heterogeneity.

Against this background, a central theme in the development of KA is the presence of institutional mechanisms that allow:
- a collective management of spatial externalities (water erosion on hillsides and integrated pest management are just two examples of the need for joint activities);
an appreciation by relevant actors of all human activities related to the use of land resources in the rural space of the watershed, and not just those related with agricultural activities.

In this context, ‘innovation networks’ appear as the basic institutional structure for developing knowledge-based agricultural models. Such voluntary organisations are built to serve common purposes by exploiting the complementary capabilities resulting from the confluence of a set of heterogeneous actors. To accomplish this, networks should:

- Create flexible environments to disseminate information and technologies, through learning processes based on the interaction among members;
- Allow consensus-building on strategic questions and operational methods, resulting in the assignment of responsibilities on the basis of agreed tasks;
- Facilitate the establishment of strategic alliances among actors, and for resource mobilisation around concerted efforts.

These innovation networks could link the macro- and micro-watershed level arrangements mentioned when discussing the institutional dimension of KAs (4.3.3.). At the same time, such innovation networks need to link to other organisational mechanisms providing them the necessary scientific and institutional information required by innovation processes. This could be achieved through agreements and strategic alliances among governmental, parastatal, industrial, producer, non-governmental and community organisations, together with NARS and IARCs; constituting agricultural information systems. They will keep an innovation focus, articulating their needs to regional and global sources through the application of modern information and communication technologies.

One interesting case of what could be called an innovation network is that of PanelaNet, promoted by CORPOICA in Colombia and developed by producers of ‘panela’ (brown sugar produced in “trapiches” by very small), extensionists, researchers, development agents that manage credit, and marketing people. Information activities include the selective dissemination of research results, a question and answer service, electronic discussion groups, and technical assistance to producers feeding-back to research organisations. Actors in this multi-stakeholder network were brought together as a result of abilities and capacities developed in the process of sharing information, common perceptions and interests perceived in dialogues, and opportunities and advantages identified for collaboration. The network has developed into a Regional Research and Information Network on Panela, with the participation of actors from Brazil, Peru, Dominican Republic and other countries from the region.
REFERENCES

In the process of developing this document we have made a liberal use of information, concepts and ideas published by many authors. The following is a preliminary list of consulted articles/books, which will be completed and properly cited in the next version.


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Torres, F., and G. Gallopín, 1994. Systems Research Methods and Approaches at CIAT: current and planned involvement. In Opportunities, Use and Transfer of...


Fig. 1: Corporate Control of Global Commodity Trade

- Wheat
- Sugar
- Maize
- Coffee
- Rice
- Cocoa beans
- Tea
- Bananas
- Pineapples
Fig. 2: Urban and Rural Populations in Developing Countries

Years

Billion People

Fig. 3: Population Below $1/day

[Graph showing population below $1/day from 1986 to 2000 for different regions: E-Asia & Pacific, L-America & C, M-East & N-Africa, South Asia, S-Safrica, and Total. The graph indicates a decrease in population over the years for all regions.]
Fig. 4: Population Below $2/day
Fig. 5: Poverty Scenarios
(for $1/day)
Fig. 6: World Cereal Yield Growth Rates
(1961-93, using 5-yr moving average)
Fig. 7: Balance of Agricultural Imports and Exports in Sub-Saharan Africa

Billion Dollars

Years

Imports
Exports
Fig. 8: Total Cereal Yields

Cereal Yields (t/ha)

Developed Countries
Developing Countries

Years
Fig. 9: Total Maize Yields
Fig. 10: Total Wheat Yields

The graph illustrates the total wheat yields in developed and developing countries over the years from 1955 to 2000. The y-axis represents yield in t/ha, ranging from 0 to 3. The x-axis represents the years from 1955 to 2000.

- The blue line represents developed countries, showing a steady increase in yield.
- The red line represents developing countries, also showing a steady increase in yield.

The data indicates a consistent growth in wheat yields for both developed and developing countries, with developing countries starting at a lower yield but closing the gap by the end of the period.
Fig. 11: Undernourished and Total Population

- S-Safr
- NE&NA
- LA&C
- OtherA&P
- India
- China

[Bar chart showing undernourished and total population for different regions, with China having the highest undernourished population.]
Fig. 12: Global Land Degradation

<table>
<thead>
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<th>Land Use Type</th>
<th>Area (billion ha)</th>
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<tr>
<td>Pasture</td>
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<td>Forest</td>
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<td>Total</td>
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