# IAASTD GLOBAL REPORT CHAPTER 2
# HISTORICAL ANALYSIS OF THE EFFECTIVENESS OF AKST SYSTEMS IN PROMOTING INNOVATION

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## Key Messages

**The outcome of past AKST events depends on the contextual, historical and political conditions of institutional arrangements and actors engaged in specific situations.** Contextual analysis of institutional feasibility is essential for developing innovations that move towards Bureau goals. Decentralization of funding and capacity development is required.

**Past AKST have shown preferences for short term vs. long term, for powerful voices over the unorganized and voiceless.** Development of prospective and participatory methods, procedures and poverty sensitive analytical tools as well as re-strengthening of public support and regulatory interventions are needed.

**Public/private partnerships can move AKST towards bureau goals.** Multiplication of this type of institutional arrangements in a way accountable to the Bureau goals (see k.m.N°2) is to be promoted.

**Civil society groups have been effective in changing the nature of AKST arrangements.** Acknowledgment and support of civil society groups and integration of their knowledge and findings in the design of policies are necessary

**Human values (solidarity, ethics, culture, identity etc.) as well as commercial interests can drive innovation in AKST -- e.g. fair trade and community supported agriculture.** Development of public frameworks in which such human values and collective processes are fostered have to be supported to become effective drivers of AKST.

**The ultimate knowledge synthesis for action is made by farmers and laborers.** In some cases farmer and women groups have been effective (Bureau goals) in knowledge production and technical development in different ways in different settings. This has been insufficiently recognized. AKST actors need to collaborate to include societal needs, concerns and capacities of such groups thus empowering them.

**Institutional arrangements that work in one setting cannot be transferred to other settings in the expectation they will work in the same way.** Capacity, understanding and knowledge cannot be separated from actors and context. Hence, regulatory frameworks, educational curricula, institutional arrangements etc., need to be developed and implemented with the actors in each context.

The tension between scientific incentives faced by individual scientists, who are mainly judged on purely academic criteria of 'scientific excellence', assessed on the basis of peer reviewed publications, and the societal demands placed on scientific institutions has been growing in recent decades. **It now poses a huge challenge for the governance of scientific institutions dedicated to AKST.**

## 2.1. Science, Knowledge, Technology, and Innovation

This chapter focuses on knowledge, science and technology (KST), and how these have been brought to bear on agricultural problems, and combined to bring about innovation. It uses definitions of KST and innovation to assess the roles that various knowledge actors have played in key agro-ecological contexts, noting changes over time. The dominant institutional arrangements for organizing knowledge processes are assessed in relation to the major roles and contexts identified, i.e., in terms of agricultural paradigms. The conceptual and operational implications are synthesized by means of typologies, constructed diagrammatically, in order to highlight and assess the drivers of AKST and innovation, at three levels – local, regional, global - and across five agricultural paradigms. The assessments are further elaborated in terms of four thematic narratives – (1) genetic resources management; (2) pest management; (3) food safety, security, and sovereignty; and (4) soil and water management.

During the post-war period, a first division of work assigned seed production and agricultural production to different sets of actors. It resulted in a top-down innovation process wherein standardization and scale economies for breeders were paramount. Moreover, the rigidification of IPR weakened the mutualization of genetic resources among breeders who developed new industrial strategies based on the generalization of utility patents and on the spreading of gene technologies.[these 2 sentences are not understandable outside a limited academic world. I think this is what we mean: During the early 1950s, following the second World War, the need quickly to restore production capacity and boost productivity led to centrally directed investments and top-down organization of innovation processes.  These models progressively revealed their shortcomings, particularly in terms of the ecological and social consequences of agricultural productivism, at local, regional and international levels. Various approaches to dealing with agro-ecosystem sustainability met with considerable success, while renewed interest in livelihood development and progressive urbanization alleviated some aspects of agrarian distress. Throughout this period, agriculture and food systems became increasingly dependent on fossil fuel energy and chemicals to sustain their efficiency and productivity, leaving them vulnerable to oil pricing shocks and to environmental and human health hazards. More recent claims that genomics and more broadly, bioscience, can deliver productive, environmentally safe, and profitable farming and food systems have become caught up in debates about food safety, security, and sovereignty and in reactions to the industrialization of food and the IPR and patent protection that surround genomics.  In developing countries, on the one hand, development and sustainability goals are not being met; on the other hand, in developed countries and emergent economies, food markets require a wide range of diverse qualities. Food and farming systems have produced perverse outcomes:  an estimated 850m hungry and over 1m obese; highly productive agricultures but declining agro-environmental quality and loss of biodiversity; ample commodity food supply but widespread loss of diversity in food cultures. In this chapter we assess the ways in which these outcomes have been brought about, the increasing separation between researchers and producers, and recognize the value of an increased role for user knowledge in the

design of innovation. We conclude that local arrangements between producers and researchers may improve the likelihood of achieving development and sustainability goals.
The evidence points towards an increasing technical and policy support for participatory ecologically-based decision making by farmers. Farmer Field Schools are one way forward; rural school curricula development is another. Strong and enforceable policy frameworks have been shown to be necessary for promotion of the transition, as well as public sector and donor agency investment in agricultural research and extension that purposefully searches for ecological and sustainable options, and that builds effective engagement among farmers, health, water and environmental agencies. Innovative public-private partnerships in which farmers and the public good are front and center, offer powerful mechanisms to enable societal shifts towards sustainability. But these arrangements are not guaranteed to develop without political commitment to development and sustainability goals.

### *2.1.1 The specificity of agriculture as an activity sector*

Because of the specificity of agriculture, a characteristic which is itself very controversial, knowledge, science and technology processes in and around that sector have specific characteristic which must be understood and fully taken into account in any meaningful assessment of what AKST has contributed in the past to broader development goals and of the challenges to be met for the full potential contributions of AKST to the Millennium development goals to be achieved, i.e. the purpose of the whole IAASTD exercise.

This part begins by defining what is special about KST when applied to agriculture. One must remember that agriculture is a human activity, a craft based on location specific biological processes, which interact with their biophysical/ecological context, this context itself evolving independently, to a large extent, of agriculture. It follows that AKST includes both a set of independent activities, that happen to be dealing with the particular domain of agriculture, and activities that necessarily co-evolve with the development of numerous other parameters. AKST thus involves many types of knowledge, and many suppliers of that knowledge, as agriculture entails vast numbers of (semi) autonomous enterprises and decision makers.

The specificity of agriculture is controversial however. The main controversy took place first in GATT, now WTO, where critics of protectionist policies, justified in the name of the specificity of the sector, have forcefully argued that such policies were detrimental and should be reformed, leading to the position that this specificity did not really matter. It is thus necessary to review briefly the terms of that debate in order to assess its implications for AKST. But first several important and non-controversial characteristics of agriculture will be briefly reviewed.

#### 2.1.1.1 Specific characteristics of agriculture

*A place-based activity.* Agriculture is a place-based activity that relies on a unique combination of bio-climatic conditions and local resources in their natural, socio-economic and cultural dimensions. Agricultural practices, depend on, and also influence, these conditions and resources. Specific knowledge of the locality is a decisive asset that cannot be restricted to the application of a set of ready-made recipes, although it often has been ignored or undervalued by the many “blue-print” approaches to agricultural development in the 20th century. The co-evolution of AKST increasingly has been driven by non-local changes, a trend that has been tightly associated with a science-based approach to agriculture, as described in the following subsection. This has led to greater control of production factors, and the simplification and homogenization of production situations (Allaire, 1996). However, more recent advances in science, and counter-currents driven by civil society, as discussed below, have begun to foster a more ecological approach appreciative of place-specific opportunities (Fresco, 2002).

*An embedded activity.* As a consequence of its specificity, agriculture is as heterogeneous as bio-climatic conditions, local resources and local actors are. This diversity generates flows of products and services that depend on a web of institutional arrangements and relationships, at varying scales, such as farmers’ organizations, industrial districts, commodity chains, *terroirs*, production areas, natural resource management areas, ethnic territories, administrative divisions, nations, and global trading networks. Farmers are simultaneously members of various arrangements and relationships that frame the opportunities and constraints they face; and these lead to incentives which are sometimes contradictory . To take full advantage of these specificities, farmers require a strategic ability to select and interpret the relevant information produced in the different arrangements and relationships in which they are embedded (Chiffoleau and Dreyfus, 2004).

*A collective activity.* Farmers react to the constraints and opportunities according to the various resources (physical, financial, human, social, environmental, symbolic) that are available to them. Access to the varying capital stocks, and opportunities to create new capital wealth, are not equally distributed in society or within households. Individuals, groups, and communities develop relational skills and capacity for collective action that help them to protect or enhance their access to, and use of, capital stocks. New forms of collective action have emerged in relation to the new commercial actors who have become more dominant in food and farming systems as a consequence of demographic change, the requirements of markets, and the geo-political flow of agricultural and food trade (Barbier and Lémery, 2000).

*A disadvantaged activity.* Agriculture for the majority is disadvantaged in the sense that the majority of the numerous smallholders and farm workers, in developing countries particularly, have suffered exclusion from formal education, science and technology. In rural areas, children’s access to education is much lower in comparison with urban areas, the rate of adult illiteracy is higher, the quality of education is worse and frequently unsuitable for the development of a specific expertise linked to both the subsistence and the development of the rural communities. Wherever the structural and systemic disadvantages have been coupled to a lack of effective economic demand among cash-poor households, poor farmers have been excluded from formal decision making in agriculture and food policy, particularly from priority setting in agricultural research. They have experienced exploitation in commercial relations (Newell and Wheeler, eds. 2006). In addition, as pointed out by

Mazoyer and Roudard (2005), the economic marginalization of large numbers of farmers is growing as it is driven by a huge and growing gap in the average productivity of labor between small peasants, relying mainly on hand tools, and a much smaller number of farmers, having motorized and mechanized their operations, contributing a larger and larger share of market deliveries, weighing on prices and thereby contributing to the secular downward trend in prices of agricultural prices observed until recently.

Among poor farmers, women are generally very disadvantaged, as reflected now in a large body of literature on gender demonstrating that the relations between men and women and the roles that women and men may assume are culturally and institutionally embedded. (ISNAR, 2002). Already in 1970, Boserup (1970) pointed out the diversity of roles of women depending on the type of agriculture (hand tools, animal traction, degree of mechanization) being practiced. Rural time allocation studies conducted in the 1970s and 80s, summarized by (Buvinic and Rekha, 1990) documented that diversity and the generally lower status of the tasks conducted by women.  Today, widely cited estimates of women's contributions to agricultural and food systems range from 40 percent in Latin America to 60 and 80 percent in Asia and Africa. These figures were estimated from analysis of trend data for 1950 to 1990 carried out by the FAO for the 1996 World Food Summit, but they have a weak statistical base; actual participation rates vary considerably between contexts (Goldberg et al, 1998) with some areas currently experiencing increasing participation while others are witnessing a reduction in women's participation in farming (Diarra and Monimart, 2006)

In spite of the importance of the tasks fulfilled by women, AKST institutions do not give them a commensurate degree of attention. Thus, it has been estimated that women farmers still receive only 5 percent of all agricultural extension services worldwide (Rojas, 2006). In addition, it has been found in Africa that extension workers, who are often male, assume limits on women's capacity to absorb information and leave out points that they (not the women) consider too technical (Muntemba and Chimedza, 1995).

All  these disadvantages matter: for example, the higher the rate of rural illiteracy, the greater the rate of rural child under-nutrition (FAO, 2004). Girls and adult women have been, and remain, especially disadvantaged, although the social gains of reducing gender disadvantage are well proven. For instance, the higher the percentage of girls enrolled in school, the lower the child malnutrition rate (FAO, 2004) This disparity in access occurs even though all over the world, agricultural tasks have been found to be gender specific and an overwhelming body of evidence points to women's substantial contributions to agriculture production and marketing, food system management, and nutrition (e.g., Mock, 1976; World Bank, 1999; IFAD, 2003).

2.1.1.2 The controversy on multifunctionality

Agriculture is an economic activity providing multiple benefits to human society. However, agricultural activities also have direct impacts on the environment (e.g., nutrient cycling, soil protection and productivity, pollination, biodiversity, water quality, carbon sequestration, flood control), and provide a habitat for semi-domesticated and wild species of plants and trees, as well as for birds, amphibians, small mammals, insects and soil organisms. These environmental and ecological functions are essential for the sustainability of agriculture itself, but also for other economic sectors, and for society as a whole (http://www.multiagri.net).

These roles are well recognized and non-controversial. The controversy in WTO started when rich countries such as Japan, Switzerland or Norway, in addition to the European Union, put forth the multiple roles of agriculture as a new rationale for providing financial support to the sector. The countries advocating trade liberalization: United States and members of the Cairns group, such as Australia, New Zealand or Australia, raised strong objections because they saw in that claim by the 'friends of multifunctionality' a regression from the process of trade liberalization and domestic policy reform which had been painfully negotiated during the Uruguay round of trade negotiations. (De Vries (2000) noted that the term first gained popularity in countries that were under tremendous pressure to reduce subsidies and trade protection for their domestic farmers). The fact that the countries who declared themselves the 'friends of multifunctionality' were those who had been the most reluctant to commit to reform heightened the fears of the countries supporting freer trade. This controversy led to a stalemate on the issue in WTO, with consequences still lasting until today. Analyzing those would be well beyond the scope of this assessment.

From the WTO, the debate moved to OECD and FAO, leading to a clarification of the policy issues and a broad recognition that agriculture does play multiple roles. Additional benefits associated with agriculture include food safety and food security, animal welfare, cultural and historic heritage values, and the livability and viability of rural communities (Cahill, 2001; Hediger and Lehmann, 2003). The main thrust of agricultural policy over the last 60 years, however, has regarded agriculture mainly as a production activity contributing directly to rural incomes and rural employment, and neither the environmental costs of the technology employed, nor the social costs to rural communities and urban areas of the rapid loss of labor from farming and decreasing farm numbers, have been systematically quantified (Pretty, 2005; Pretty and Waibel, 2004; Pimentel et al., 1992, 1993). The impact on civil order of large numbers of young people desirous of a modern life but who have no prospect of waged employment yet no future in farming only recently has come to be understood in any depth (Richards, 2005).

The FAO project, Roles of Agriculture, identified these roles of agriculture at different scales (Table 2.1; http://www.fao.org/es/esa/roa/index_en.asp). The project's country case studies underlined the many cross-sector links through which agricultural growth can support overall economic growth and highlighted the balance between rural and urban populations, social stability and integration, improved food safety, and traditions and culture as important to sustainable farming.

INSERT Table 2.1 Here

In recent decades, changes in consumer demand (including renewed emphasis on food quality, ethical issues, rural community livelihoods), as well as changes in policy concerns (including resource conservation, energy use and environmental sustainability), have stressed the need to build a new contract between agriculture and society (Röling, 2005).Policy makers have been driven to look for trade-offs between sectorial approaches and area-based approaches to agriculture, rural development, and resource conservation (Hediger and Lehmann, 2003; Cahill, 2001).
The concept of "multi-functionality" (as illustrated in Figure 2.1.) refers to agriculture as a multi-output activity producing not only commodities (food, fodder, fibers, bio-fuel and recently pharmaceuticals), but also non-commodity outputs, such as environmental benefits, landscape amenities and cultural heritage, which are not traded in organized markets (Blandford and Boisvert, 2002). The frequently cited "working definition" proposed by OECD (2001), in turn, associates "multi-functionality with particular characteristics of the agricultural production process and its outputs: (i) the existence of multiple commodity and non-commodity outputs that are jointly produced by agriculture; and that (ii) some of the non-commodity outputs may exhibit the characteristics of externalities or public goods, such that markets for these goods function poorly or are non-existent."

INSERT Fig. 2.1 Here

2.1.1.3 Implications for AKST

Several of the variables associated with the multiple roles of agriculture are difficult to assess and require the development of new knowledge routines. Indeed, measurement of the overall contributions of agriculture is necessary to the design of agricultural policies that aim at delivering more sustainable outcomes. However, the ecological and social goods, services and amenities that are not subject to commercial transactions have proven difficult to measure and hence greater reliance has been placed on relevant and efficient proxy indicators (Akca et al., 2005). Various accounting models and procedures are under development, for instance to create environmentally adjusted macro-economic indicators for national economies (O'Connor, 2006), that are better able to deal with multi-functionality, but "In practice, all…..face limits in their coverage of environmental phenomena" (O'Connor, 2006:92). The various frameworks that are in use have revealed major shortcomings in contemporary agricultural practices. A study of data from 14 states in India, for example, showed that rapid economic growth has led initially to equally rapid decline in environmental quality, as measured by a range of natural resource and pollution indices, with severe effects on the livelihoods particularly of rural poor people (Mukherjee and Kathuria , 2006).

An increasing body of evidence shows that the trend toward environment-friendly agriculture based on ecological understanding increases the importance of place-based knowledge and locally generated options for managing agriculture, because an ecological context is always and necessarily 'situated' and cannot – unlike commodities, or functions such as water use or carbon trading– be physically exchanged (Hubert et al., 2000; Lal et al., 2005; Steffen et al. 2004). 'Relationships of value' that connected those willing to pay for specific ecological values, and those who managed the resources that are valued, began to emerge from the mid-1990s, mobilizing new kinds of informal AKST networks as well as specialist expertise. Examples include urban councils using rate levies to pay for the maintenance of surrounding recreational green space, farmers accepting payment for periodic 'water spreading' on their fields in times of flood, farmers' markets, community-supported agriculture, and 'rich world' individuals (out of concern for conservation of tropical species and parks in poor countries) providing funds to natural park management that support both poor producers within the park, and park rangers in their conservation functions.

### *2.1.2 Knowledge processes*

The phrase 'knowledge processes' refers to the collective processes of creating, transforming, storing, and communicating about knowledge (Beal et al., 1986). For much of the last 60 years, the organization of knowledge processes in agricultural development has been subsumed in powerful mental models of how science, knowledge and technology 'get agriculture moving' (Mosher, 1966). Several such mental processes have been identified here, recognizing that each one has its own logic and fitness for purpose. These are now discussed and compared in some detail

2.1.2.1The Transfer of Technology model and diffusion processes.

One model in particular has dominated as a guide to the organization of knowledge processes in the public sector in developing countries, the Transfer of Technology (ToT) model (Fig. 2.2). It is based on a somewhat simplified interpretation of various experiences, mainly in developed countries, and was formally elaborated on the basis of empirical studies of knowledge dissemination processes in the mid-west of America (Havelock, 1969; Lionberger, 1960). In this model, Science is positioned as a privileged problem-defining and knowledge generating activity carried out by universities and research stations, whose knowledge, embedded in technologies, messages, and practices, is transferred by extension agents to farmers. The model assumes a linear flow of technological products and information. Although in practice, much local level interaction takes place and is even encouraged between extension agents, farmers, and research specialists, the underlying assumption of the model is that farmers are relatively passive cognitive agents whose own knowledge is to be replaced and improved (Röling, 1988; Röling and Wagemakers, 1998).

INSERT Fig. 2.2 Here

The model mirrored the prevailing AKST organizational arrangements of states gaining their independence in the 1950s and 60s. Many explicitly favored centrally-planned economic development, and most relied heavily on state organizations as the catalyst of agricultural development and commodity marketing. Extension field staff were positioned on the lowest rung in a hierarchy of relationships under the direction of departments of agriculture and publicly funded research stations and universities (Maunder, 1972). Social, educational, and political biases served to reinforce the idea that lack of access to 'modern knowledge' was a constraint to production and that without new technology and therefore new modern knowledge, farmers were incapable of self-development

(Morss, et al., 1976). The model also mirrored, in organizational terms, the presumptive power of technology to effect ‘action at a distance’.

The ToT model assumed wide impact on the basis of autonomous diffusion processes (Rogers, 1962). The classic study of *diffusion of innovations* had been published in 1943, based on the rapid autonomous spread of hybrid maize among farmers in Iowa (Ryan and Gross, 1943). For some time, the diffusion of innovations became the single most popular subject for empirical social science research, generating well over 2000 studies, even after the late Everett Rogers (well-known for his classic overview of research on the diffusion of innovations, e.g., Rogers, 1995) himself spoke of the ‘passing of a dominant paradigm’ (Rogers, 1976). Autonomous diffusion among farmers none the less has persisted as one of the pillars of the common understanding of the pathways of science impact. The rapid and autonomous spread of introduced crops such as cassava, maize, beans, cocoa, and many other crop species and cultivars in Africa is testimony to the power of unaided diffusion processes to change the face of agriculture.

*The positive impact of the ToT Model*. The ToT model gained enormous credibility from the rapid and widespread adoption of the first products of the Green Revolution (GR) emerging from basic and strategic research (Evenson and Gollin, 2003; Evenson, 1986). For example, in the poor, populous, famine-prone areas of Asia, the GR allowed Bangladesh to move in twenty-five years from being a net importer of rice to self sufficiency while its population grew from 53m to 115m (Gill, 1995); and India, Indonesia, Vietnam, and Pakistan to avert major famine and keep pace with population growth (Repetto, 1994). In China, wheat imports dropped from 7.2m t in 1994 to 1.9m t in 1997 and by 1997 net rice exports had risen to 1.1m t. The Green Revolution not only increased the supply of locally available staples but also the demand for farm labor, increasing wage rates and thus the work-based income of the ‘dollar-poor’ (Lipton, 2005). National food security in food staples in the high population areas of developing countries throughout the world was achieved, except in sub-Saharan Africa. The diet of many households changed as more milk and meat became available (Fan et al., 1998). Investment in industrialized food processing and in agricultural engineering, often stimulated by heavy government subsidies, in turn began to transform subsistence farming into a business enterprise and created new employment opportunities in post-harvest operations, i.e., storage, milling, marketing and transportation (Sharma and Poleman, 1993). The prevalent assumption was that easy access to cheap fossil fuel energy, which underlies this approach to modernization, would continue far into the future.

The ToT model clearly proved fit for the purposes of disseminating improved seed, training farmers in simple practices and input use, and disseminating simple messages within the intensive production systems characterizing the relatively homogenous irrigated wheat and rice environments of South and Southeast Asia. It legitimized the so-called Training and Visit (TandV) system of extension, which had first been experimented in southern Turkey (Benor and Baxter, 1984). The ToT model fitted the norms of socio-political contexts characterized by strong state power and social deference to persons considered more powerful and of higher status. Nonetheless, poor organization of the distribution of inputs and services, malfunctioning markets, mismanagement and diversion of public funds, loss of entitlements, civil unrest and war left many millions still vulnerable to malnutrition, hunger, and starvation (Sen, 1981; FAO 1995a; Johnson, 1996).

Parallel but distinct developments meanwhile were occurring in the private commercial sector. One model that in the post-WWII period was widespread in commercial practice was associated with estate production of tea, coffee, palm oil, rubber, pineapples and similar commodities: the core-estate-with-out-growers model. Producers were placed in a contractual relationship to supply outputs to a processing facility, which provided the inputs and services necessary to sustain supply to the facility. The company assumed responsibility for assembling the science-based and market knowledge, and the technology and infrastructure required for securing company profits, drawing largely on knowledge resources in the home country or from within the company's international operations.

*The ToT model's failure to meet development and sustainability goals.* Criticism of the ToT model began to emerge strongly in the late 1970s, as evidence of negative socio-economic and environmental impacts of the GR became clearer (UNRISD, 1975; Freebairn, 1995) leading to sharp controversies which are still alive today, as technological pathways to increase productivity became less simple (Collinson, ed. 2000), and as additional goals beyond increases in yield and profitability were added to the development agenda. A crucial consideration was assurance that the institutional and economic conditions for using a new technology were in place. In many instances these conditions were simply lacking or performing poorly for the resource-poor, the indigent, the marginalized, and for women (Swanson, 1984; Jiggins, 1986; Ladejinsky, 1977; Hunter, 1970). The evidence highlighted three areas of concern:

- *Empirical*: the ToT model was shown to be unfit for organizing knowledge processes capable of impacting heterogeneous environments and farming populations (Hill, 1982 ), did not serve the interests of resource-poor farmers in risky, diverse, drought prone environments (Chambers, 1983) and often gave rise to no benefit or negative consequences for women (IRRI, 1985); in addition, the improved seeds rapidly displaced much of the genetic diversity in farmers' fields that sustained local (food) cultures (Howard, 2005) and which had allowed farmers to manage place-dependent risks (Richards, 1985); and the higher use of pest control chemicals had detrimental effects on beneficial insects, soils and water (Kenmore et al., 1984; Georghiou, 1986) as well as on human (Whorton et al., 1977; Barsky, 1984) and animal health.
- *Theoretical*: the basic assumption of the ToT model, that 'knowledge' can be transferred was shown to be wrong: it is information, and communications about others' knowledge that can be shared rather than knowledge itself; no-one is merely a passive 'receiver' of information and technology since every one engages in the full range of knowledge processes as a condition of human survival (Beal, 1986). Further, information about people's knowledge, attitudes and practices was found to be a poor predictor of their response to new ideas, messages, or technologies, because knowledge processes and behaviors are interactive with the dynamic of their environment. The presumption that a

specialized cadre of knowledge workers could be empowered to 'engineer' the development outcomes for millions of the world's people also was challenged on ethical grounds. It was argued, especially by civil society actors, that however benign the intentions, to do so is to deprive individuals, communities, an*d* indeed national governments, of their right to be agents of their own development (Jones, 1987).

*Practical: the mix of organizational support and services needed to gain maximum impact from* the ToT model often were lacking, poorly performing, imposed high transaction costs, or were not accessible to the poor and/or to women (Howell, 1982). The credit markets introduced to support technology adoption, for instance, typically were selective and biased in favor of resource rich regions and individuals (Freebairn, 1985). The evidence of negative effects on equity were claimed by some to be a first generation effect. Analysis of data from the Northern Arcot region of Tamil Nadu, India, indicated that the differences in yield found between large and small farmers in the 1970s had disappeared by the 1980s (Hazell and Ramaswamy, 1991) but further empirical studies failed to resolve the extent to which the second generation effects were the result of 'catch up' by later adopters or the result of smaller farmers having lost their land or migrated out of farming. A recent authoritative assessment concludes that after 'twenty-five years in which agricultural extension received the highest level of attention it ever attracted on the rural development agenda' (Anderson et al., 2006 :168), political support for TandV in the form of 'relatively uniform packages of investments and extension practices in large state and national programs' had disappeared (Anderson et al., 2006 :167). Fiscal sustainability, the need for flexible responses to local need and opportunity, market pressures, and the demonstrably effective alternative of working with empowered clients and lower cost organizational arrangements, are among the reasons cited for the passing into history of the TandV model.

2.1.2.2 Innovation in the organization of knowledge processes.

By the early 1970s, empirical studies and better theoretical understanding of the communication, diffusion, and cognitive processes at work indicated that better mental models of knowledge processes were needed to guide practice if broader development goals were to be reached (Hunter, 1970). The first wave of innovation in non-Communist states sought to make more effective the process of moving science 'down the pipeline' and technologies 'off the shelf' on the basis of the ToT model, by creating feedback from producers, so that their local knowledge and priorities could be taken into account in selecting what was sent down the pipeline and taken off the shelf, and in targeting their specific R&D need. In the case of the Training and Visit (TandV) approach, which was heavily supported by the World Bank and became standard practice in the majority of non-communist developing countries, feedback was accomplished by requiring extension agents to report back 'up the line' the problems and priorities of the farmer and farmer groups that they trained during their fortnightly field visits (Benor and Baxter, 1984) The TandV approach relied also on diffusion effects to achieve wide impact, in this case assisted by the 'leading farmers' and farmer groups convened under the TandV schedule.

In the case of Farming Systems Research and Extension, feedback was accomplished directly through diagnostic surveys carried out by multi-disciplinary research teams, by farm level interactions between research teams and farmers in the course of technology design, testing, and adaptation, and by the organization of farmer visits to research stations (Collinson, 2000). Wide impact in this case was sought by the designation of farming systems within agro-ecological ‘recommendation domains’ for which a specific technology or practice was designed to be effective and profitable.

However, neither TandV nor FSR-E addressed the institutional challenge of creating ‘the mix’ of support services necessary for articulating innovation along the chain from producer to consumer (Lionberger, 1986). This challenge was directly addressed in Communist states, by state seizure of the means of production, and by state control of the provision of inputs and services and of the distribution of the product. The scientific knowledge base to support such a high degree of planning was strong. However, the means chosen within the prevailing ideology to translate knowledge generated at the scientific level into knowledge that was effective for practice was based on *command and control.* Support to the knowledge processes and experiential capacity of those actually working the land – albeit under direction of others – was not encouraged. The command and control approach did not prove effective in generating continuing innovation in agriculture and became a source of vulnerability for the very survival of such states (Gao and Li, 2006). Since the fall of the Berlin Wall in 1989, the command and control model has been largely abandoned.

*Farmer Participatory Research and Extension.* A second wave of innovation in the organizational design of knowledge processes in non-communist states was centered in producers’ own capacity to engage in ‘knowledge work’ and in the central role of local organizations in meeting development and sustainability goals (Chambers and Howes, 1979; Chambers, 1981). Models for what became known as Farmer Participatory Research and Extension (FPR&E) were elaborated in practice, drawing on local traditions of association, knowledge generation, and communication (Fig. 2.3). They shared a number of generic features *viz.* learner-centered, place dependent, ecologically informed, interactive communication (Chambers and Ghildyal, 1985; Farrington and Martin, 1987; Biggs, 1989; Haverkort et al., 1991; Ashby, 1986; Ashby, 2003). Science and off-the-shelf technologies were in these instances positioned as stores of knowledge and potential, and as specialized problem-solving capacities, that could be called upon at will, as needed in the context of specific innovation opportunities. Non-government organizations (NGOs) and community-based organizations (CBOs) played key roles in elaborating effective practice and supporting local FPR&E initiatives (IIRR, 1996; 2005). Participatory Plant Breeding is one domain where a client-oriented interactive approach has been shown to be particularly effective, for both grains and roots (Farrington and Witcombe, 1998; CIAT, 2001; Chiwona-Karltun, 2001; Mkumbira, 2002; Ceccarelli et al., 2002).

INSERT Fig. 2.3 Here

Wider scale impact in the case of FPR&E relied on the replication of local level initiatives, farmer-to-farmer networking, and support to farmer driven chain development (as in poultry or dairy chains serving local markets) (UPWARD, 1997), and in the creation of ‘learning alliances’ among support organizations that aimed to promote shared learning at societal scales (Pretty, 1994; Lightfoot et al., 2002). FPR&E proved to be cost-effective and fit for the purposes of meeting integrated development and sustainability goals (Bunch, 1982; Hyman, 1992). However, the approach has been criticized for failing to take advantage of the 'best' science and technology available, as self-indulgent, supporting farm systems that are insufficiently productive to meet the needs of the world's growing urban populations, and as populist, yet incapable of involving a sufficient number of the millions of small farmers (Biggs, 1995; Richards, 1995 ; Cooke and Kothari, 2001). The controversies over what the empirical evidence means arise principally in terms of the frames of reference and pre-analytic values used to interpret the evidence.

Innovation in multi-functional agriculture often has been associated with FPR&E, drawing on farmer-developed traditions of agro-ecological farming (e.g., Fukuoka, 1978; Furuno, 2001) as well as on scientific studies. This indigenous capacity for innovation has contributed, for instance, to the development of organic farming (variously known as biological or eco-agriculture) and has been codified in, for example, permaculture (Holmgren, 2002; Mollison, 1988). Systems such as these tend to use less or no externally supplied and synthetic inputs, seeking to generate healthy soils and crops through sustainable management of agro-ecological cycles within the farm or by exchange among neighboring farms; the relative lack of firm evidence of the sustainability and productivity of these systems allows both proponents and critics to hold onto entrenched positions about their present and potential value (Tripp, 2005; Tripp, 2006a). However, a recent comprehensive assessment of the literature demonstrates that although low external input technology has its limitations, better use of local resources in small scale agriculture can improve productivity and innovation (Tripp, R., 2006b).

*Indigenous knowledge and farmer-scientist research models*. Indigenous knowledge (IK) is a term without exact meaning, but is commonly taken to refer to locally bound knowledge that is indigenous to a specific area and embedded in the culture, cosmology, and activities of particular peoples. Indigenous knowledge processes tend to be non-formal (even if systematic and rigorous), dynamic, and adaptive. Information about such knowledge is usually orally transmitted, but also codified in elaborate written and visual materials or artifacts, and relates closely to the rhythms of life and institutional arrangements that govern local survival, subsistence, and well being (Hounkonnou, 2001). IK can be seen as systematic bodies of knowledge that are tested through experience, exact observation, and informal experimentation, situated in the life world of a particular group of inhabitants, and grounded in their existence in a specific place and culture (Warren and Rajasekaran, 1993). Fifity years' ago IK was neglected except by a handful of scholars; it is seen today increasingly as a valuable asset. Under the ToT model, agricultural S, T, and D, including rural extension services, have not formed effective partnerships with the mass of small farmers; extension services have rarely contacted even sporadically more than 20-30 percent of the population in these areas except under the stimulus of special investment programs or projects (Röling, 1998).

Yet, it remains that IK processes have ensured the development and cultural evolution of humankind; they continue to ensure the survival of some two-thirds of the world's people living in rainfed farming areas who have been only tangentially targeted by the modernization services noted elsewhere in this chapter (Balasubramanian and Nirmala Devi, eds., 2006; Millar et al., eds. 2006) Whereas the roles of women farmers in IK processes, in general, and their management of knowledge related to animal and plant genetic resources in particular (Howard, 2003), were largely ignored by both public and private sector agricultural science and by formal development services, farmers none the less often adopted and adapted the products and information flowing from the formal sector, in combination with their own autarchic development of knowledge and practice, which has continued to form their major – and often their only – knowledge resource (van Veldhuizen et al., 1997). Numerous studies have shown that the outcomes can be startling effective, at the level of both farm (Hounkounou, 2001; Brouwers, 1993; Song, 1998) and landscape (Tiffen et al., 1994).

From the 1970s onwards, a range of international foundations and non-government organizations, as well as national NGOs and community based organizations, began working locally to support IK processes and harness these in the cause of sustainable agricultural modernization, social justice, and the improvement of well-being and livelihoods (Fig. 2.4) (Boven and Mordhashi, 2002; IIRR, 1996).

INSERT Fig. 2.4 Here

A specific application of this model, that has had a high pay-off in terms of the development of portfolios of plant varieties that match poor farmers' and local market preferences and hence have been widely adopted, was Participatory Plant Breeding (PPB) or, more broadly, highly client-oriented plant breeding (Witcombe et al., 2006). Other, parallel efforts to develop client-inclusive and client-responsive R&D and farmer-led capacity building have been implemented under the rubric notably of Participatory Learning and Action Research, Farmer Research Circles, Community Forestry, Participatory Technology Development, and the FAO's People's Participation Program (Scoones and Thompson, 1994; Ashby, 2003; Coutts et al., 2005; REU, 2005; IIRR, 2005; Haverkort et al., 1991). Economic drivers originating in larger systems of interest tend to undermine the autarchic gains made at local levels or to block further development and upscaling. A new challenge to IK over the last few decades has been the emergence of Intellectual Property Rights regimes (Hardon et al., 2005; see: 2.3.1) which so far do not adequately protect or recognize individual farmers' and communities' ongoing and historic contributions to knowledge creation and technology development The perceived inequities have given rise in turn to a strong civil society response (subchapters 2.2.1; 2.2.3).

*The chain-linked model of knowledge processes*. Figure 2.5 sketches what is by far the most dominant model of knowledge processes associated with commercial innovation, the chain-linked model (Kline and Rosenberg, 1986). It has given significant impulse to the development of market economies wherever the enabling conditions exist, but has had little to offer where science organizations have remained weak, and consumer markets unable to articulate monetary demand – as in fact has been the case for much of the period among the rural and urban poor, and especially among women and other marginalized peoples.

INSERT Fig. 2.5 Here

2.1.2.3 New Challenges and Opportunities.

Over the last decade or so, changes in the balance of public and private effort and funding and in the structural relations between central and local governments have undermined the ToT model as a centrally-driven force for development. ToT continues to guide practice, but increasingly in a much more fragmented and organizationally complex context as research, extension and advisory services are privatized in whole or part (Rivera and Gustafson, 1991; Van den Ban and Samantha, 2006). One of the implications of market liberalization is that the central state loses much of its ability to direct technological choice and the organization of knowledge processes.

Decentralization and devolution of governance thus opened the space for many more instances of FPR&E. At the same time, the push for export-oriented agriculture and, in an increasing number of countries also the strong growth in domestic consumer demand, opened the space for the chain-linked model to be expressed more widely and with deeper penetration into small farming communities. In addition, the ‘core estate-with-out-growers’ model has taken on new life, as international food processors and retailers contract organized producer associations to produce to specification. Table 2.2 summarizes the fitness for purpose of each model in relation to development goals.

INSERT Table 2.2 HERE

More fundamentally, the growing recognition that knowledge processes are collective and involve a multiplicity of actors, particularly farmers, has led to giving greater attention to the role of *Information and communication processes*. Communication is now appropriately seen as an iterative process, in an ongoing dialogue between individuals, groups or organizations (Rogers and Kincaid, 1981). All parties to the communication play the roles of both “senders” and “receivers,” “encoders” and “decoders,” of information. The process was, however, shown to be neither neutral nor symmetric: empirical studies demonstrated the extent to which social, cultural and political contexts determine whose voices are heard and listened to (Holland and Blackburn, 1998).

Information and communication technology has always played its part in the process, ever since the first written works on agriculture appeared over 2,000 years ago. By the 1980s, the technologies of the digital age began to revolutionize the ability to search for and make information available. Increasingly, computer communication technologies are becoming available to populations in developing countries, as too is the infrastructure of mobile telephony; mobile telephony by end 2006 had become a US$25 bn industry across Africa and the Middle East, and Indian operators were signing up 6.6 m new subscribers a month. In the last five years low cost mobile telephony has begun to over-take the internet as the platform for information-sharing and communication, even among the poorest. For the first time, poor producers in remote places no longer have to remain cut off from market actors, or to rely on bureaucrats or commercial middlemen for timely market information. Initiatives such as TradeNet (Ghana) that connects buyers and sellers across more than ten countries in Africa, and

Trade at Hand that provides daily price information to vegetable and fruit exporters in Burkina Faso and Senegal, are having an impact that may yet rival the earlier technological breakthroughs emanating in the agricultural sciences. None the less, the rate of expansion of access to modern ICTS continues to be much greater in developed than developing countries, and among urban more than rural populations. New challenges have arisen, concerning how to avoid the new ICTs reinforcing existing patterns of disadvantage. The history of broadcast radio suggests however that over time the "digital divide" may become narrower. Low cost ICTs will become widely available and used. Issues of the quality and relevance of the information available are likely to become more important than those of access and ability to use the technology.

***2.1.3. Science processes***

The collective dimension of knowledge processes emphasized in the previous section has important consequences for the collective processes, called here science processes, involved in the creation and dissemination of scientific knowledge itself. These include processes within the scientific community but also interactions between the scientific community and other actors, particularly farmers in the case of AKST. Members of the scientific community are defined here as those who are principally involved  in such activities as pre-analytic theorizing, problem identification, hypothesis formulation, and testing through various designs and procedures (such as mathematical modelling, experimentation, or field study), data collection, analysis and data processing, and critical validation through peer review and publication, i.e. activities commonly viewed as those of the scientists. Investment in these activities by individual scientists is mainly driven by developments within science itself, given the imperative for a successful scientific career to publish in peer-reviewed journals, i.e. by definition, obtaining the recognition of one's peers in the scientific community. But scientific institutions (universities and research institutes) cannot ignore other concerns linked to societal priorities and public concern for science and for technology. This is particularly obvious in the case of such applied sciences as agricultural sciences. Thus it is not surprising that scientific activity is also conditioned by factors outside the research domain, including the changing roles of the public and private sectors, patterns of accountability, what societies choose to do with new capacities such as biotechnology and information technology, by intellectual property rights and, in the case of agricultural sciences, also agricultural production's interconnection with international commodity and food markets. This tension between the incentives faced by individual scientists and the societal demands placed on scientific institutions has been growing in recent decades and it now poses a huge challenge for the governance of scientific institutions.

For the purpose of analysis, we shall first discuss the evolution of the debates and tensions within the scientific community and then those which have taken place between the scientific community and society at large. It must however be recognized at the onset that such a formulation oversimplifies the complexity of the problems to be faced. First, the tensions within the scientific community are closely related to those between that community and society at large. And, secondly, the concept of society at large itself is questionable: different segments of society have different, sometimes conflicting, views and interests regarding scientific developments. Within the scientific community, the most significant tension for our purpose relates to the existence of different paradigms. These will be discussed first.

2.1.3.1 Paradigms, scientific cultures, and society.

Agricultural science processes in our period have been associated with two dominant intellectual paradigms: ‘positivist realism’ and ‘constructivism’. In addition, the development of systems approaches has provided an intellectual framework to integrate the contributions of diverse disciplines to the understanding of complex problems tackled by agricultural science institutions and not amenable to analyses within single disciplines. The positivist realist understanding of modern science as a neutral, universal, and value-free explanatory system has dominated the processes of scientific inquiry in agriculture for much of the twentieth century and beyond. The basic assumptions are that reality exists independently of the human observer (realism), and can be described and explained in its basic constitution (positivism).The social sciences have always found this explanatory scheme problematic, since it would appear to exclude the qualitative (even if numerate), ambiguous and highly contextualized interpretations that human subjects give to the meaning of reality and the unpredictability of the social effects of interventions made in the name of modernization (Röling, 1999).

The locus of scientific knowledge generation under the dominant paradigm remains the public and private universities, independent institutions and laboratories and, to a lesser extent, corporate research and development (R&D) facilities. In this approach to organizing science processes, farmers and farmers´ organizations depend greatly on experts (i.e., formally educated researchers) to extract true knowledge from reality by studying the immutable laws governing phenomena which allow for prediction and control. Technology is here conceived as applied science, and the main task of the agricultural sciences is to develop the best technical solutions, i.e., science is positioned as the source of innovation (Röling, 2004). This process has been classified as Mode I knowledge generation by Gibbons et al. (1994).

This paradigm has attracted large-scale support as a way of thinking about and organizing science processes for innovation in tropical agriculture. It is associated with the expectation of being able to maximize yields and compensate for shortfalls in the quantity or quality of the biotic and abiotic factors of production, by the provision of supplementary inputs, such as fertilizers, and services to improve the productivity of labor and land. As such this paradigm is at the foundation of what is often called ‘productivism’, a doctrine of agricultural modernization giving primary emphasis to increased productivity without paying attention to environmental and social implications..

The most notable consequence of the dominance of this paradigm in the academic arena has been the further division of university agricultural faculties into highly specialized departments. This split created ‘knowledge silos’ that reflected the increasing specialization of scientific disciplines and perhaps is consistent also with specialization in farming in the modern farm sectors, also in developing countries. Parallel specialization occurred also in the social sciences including: (a) a flourishing of the applied social methodologies and techniques that were needed to support cost-effective market research, advertising and sales of agricultural goods and services in the private commercial sector; (b) the growth and development of extension science in order to transfer science-generated technologies in a quick and effective way; (c) an increasing dominance of neo-classical economics in market economies, to the neglect of other human and social sciences.

The division of natural and social science activity by discipline could give rise to unproductive rivalry (Bentley, 1994). As indicated above, scientific careers being largely dependent on peer reviews and evaluation, it is one of the roots of the tension mentioned above between individual incentives and the pressures on scientific institutions to respond to societal demands. However, more inclusive and integrated science practices began to emerge from the 1970s onwards (Werge, 1978; Izuno, 1979; Agrawal, 1979; Chauhan et al. 1980; Rhoades, 1982; Biggs, 1980; Biggs, 1982; Biggs,1983). The emergence of gender studies and women in agricultural development projects (Appleton, 1995); the impact studies, analyses, and evaluations conducted by a broader range of social science researchers that showed the persistence of widespread hunger, rural unemployment and food insecurity for vulnerable populations and inter-disciplinary studies of the land degradation, water pollution, and loss of flora or fauna species associated with ‘silver bullet’ approaches, underpinned the continued evolution of inter-disciplinary and client-oriented science activity. Paradoxically, just as the strong agricultural science base developed in the Soviet bloc and in China, mainly organized on disciplinary lines, became more widely known in other parts of the world so too did the failures of the various forms of Marxist economics as guides to practical action.

The recognition of interdependent, multiple causation and complex spatial and temporal scale effects, at the heart of those environmental and social problems which subsequently led to the imperative of sustainable development, demanded new scientific approaches. The role of human choices and actions in creating unsustainable food and farming systems came to be recognized more widely. The ethical and political questions posed by scientific and technological choices came to the fore, and the separation of the natural and human sciences in agricultural R&D could not be accepted any longer. Constructivism appeared to offer a sound epistemological base for the kinds of interactive and integrative work that were called for. The epistemological position of constructivism is that reality and knowledge are actively created through social relationships and through interactions between people and their environment. These relationships and interactions are seen as affecting the ways in which scientific knowledge is produced, organized, and validated (Schütz, 1964; Berger and Luckmann, 1966). Biggs and Farrington (1991) provide an authoritative overview of the empirical research that fed the growing recognition of the institutional and political factors that affect both the conduct of agricultural science and the translation of research results into farming practices.

The founding precepts of General Systems Theory, introduced by the biologist von Bertalanffy in 1950, began to be applied to agriculture, ecology and the food chain (Spedding, 1975; Cox and Atkins, 1979;

Altieri, 1987). Systemic approaches to agro-ecology were developed strongly throughout the world in the 1980s, often led by non-governmental organizations working with small farmers on subsistence agriculture, food security, and natural resource management (Borrini-Feyerabend, et al., 2004). The boundaries of what was at stake expanded, to include on-farm fisheries, and the role of wild and semi-domesticated foods and medicines (Scoones et al., 1992) as well as forests (Ball et al., 2005). A wider range of disciplines from both social and natural sciences were recognized as needed as the issue of sustainability assumed a more prominent place in policy-making, including anthropology, demography, geography, sociology, psychology, environmental and institutional economics, politics, ecology, genomics and the environmental sciences. The agricultural sciences began to be positioned at the interface of two complex and complementary systems: natural and social systems (see fig. 2.6).

INSERT Fig. 2.6 HERE

2.1.3.2. Changing contract between science and society

In the immediate post-Second World War period there was a tacit contract between science and society based on the assumption that what was good for science was good for humanity and that science would deliver solutions to societal problems. Agricultural research institutions were created or expanded just after the war as part of the reconstruction efforts. Similarly, agricultural extension services, often public sometimes private and strongly linked to farm organizations, were launched and/or developed. The result in Western Europe, for instance, was a remarkable expansion of agricultural production. A similar process took place in Asia some twenty years later when the ‘green revolution’ was launched following the import of large quantities of seeds of high yielding varieties of wheat from Mexico in India and Pakistan. A few years later the adoption of a new high yielding variety of rice coming from IRRI spread the green revolution to the densely populated rice basins of East and south Asia. In this case also the relationship to science was direct and viewed as critical. Accordingly, investments in agricultural research and public extension increased dramatically in Asia and to a lesser extent in Latin America where the green revolution had also spread but with less spectacular results because of different and diverse conditions. The continent which was left out was Africa, particularly sub- Saharan Africa. This is not the place to enter into the often debated and still unresolved controversy of why Africa was left out. The main consequence for our purpose here is that the place of the agricultural sciences in society has never been secure, as reflected for instance in the evolution of the public financial support which they have received.1

The growing reliance of the emergent science-based agriculture on petrochemicals, and on the synthetic chemicals that emerged from scientific research in the industrial and military domains during

[1] By the turn of the century, some 40% of sub-Saharan Africa’s R&D funding was supplied from aid sources, after growing by 2.3 percent per year during the 1980s. This represented a longer-run trend for agriculture generally and agricultural R&D in particular “that began with rapid growth in spending in the 1960s, debt crises in the 1980s, then curbs on government spending and waning donor support in the 1990s. Spending growth slowed in the Middle East and North Africa as well and in Asia as a whole” (Pardey, 2006:4). By the start of the new millennium, the chronic under-funding by most developing country governments of both tertiary and field-based agricultural science, with the notable exception of Brasil, China, and India, was widely seen as problematic (Alston and Pardey, 1996; Alston et al. 1999, Alston et al. 2006). Capacity for science and technology development at the university, research institute or enterprise level in most of sub-Saharan Africa had fallen to an exceptionally low level (Gaillard and Waast, 1992), leading to what has been called the "prolonged infancy" of science in African agriculture.

World Wars I and II, initially was seen as unproblematic; indeed, these resources were seen as core drivers of the agricultural modernization agenda.

However, the increasing reliance on science and technology for national economic growth progressively revealed also the technical risks of scientific developments and resulted in a growing public mistrust in some countries of the effectiveness of science as the unqualified promoter of the public good. (Nelkin, 1975: Calvora, 1988; Gieryn, 1995; British Association for the Advancement of Science, 1999). An early sign of the public unease was highlighted by the public's response to a book by the scientist Rachel Carson, "The Silent Spring" (1962), which documented the impact on bird life and other species of the increasing use in agriculture of synthetic chemicals. During much of the 1970s and the 1980s, investment in agricultural research continued however to respond to concerns about the growing global population and food insecurity. But for the first time concerns about the finite resource base, and import substitution, also began to figure strongly in agricultural and food science research priorities (Byerlee et Alex, 1998). In the 1970s, in many countries the benefits of science and technology and their actual applications in society began to be challenged more widely by a slowly organizing civil society sector, initially mainly by the environmental movement (Gottlieb,1993; Nash, 1989; Sale, 1993; Brimblecombe and Pfister,1993; Maathai, 2003; Shiva, 2000). Science was faced both with optimism about its potential social utility and with loss of credibility when it produced undesirable results. New issues and opportunities began to emerge, such as public control over 'big science', the emergence of the private commercial sector as a major source of funding, the increasing political and military influences on scientific realms, international trade competition, as well as environmental crises. These stimulated broader debate on the role of publicly funded agricultural research. Recent decades witnessed a gradual weakening of the idea of agriculture science as a public good, and in most countries public funding for agricultural research institutes stagnated (Pardey et al. 2006). Private sector investment in research and development moderately increased (Echeverría, 1998), especially in developed countries, but the decline in public funding was a serious blow for science and technology systems in developing countries. By the 1990s only about 4 percent of the world expenditure on R&D and about 14 percent of the world's supply of scientists and engineers were in developing countries (CCSTG, 1992; UNESCO, 1993; Annerstedt, 1994). Science processes in many developing countries, especially the poorest, became heavily dependent on foreign funding and foreign training opportunities (Salomon et al., 1994; Vitta, 1993). Weakening African economies by the 1980s were devoting less than 0.4 percent of total gross national product to public R&D expenditures and the portion allotted from this to agricultural science was miniscule, especially when compared to need (Eisemon, 1986; Eisemon and Davis, 1992).

Private investment in science has tended to concentrate on technologies such as pest control chemicals, feed stuffs, veterinary products, and other technologies for which profits could be more easily captured, and more recently also on transgenic crops (Clive, 1999). Thus, scientific processes inescapably have become caught up in larger public debates. For example, the public perception of what is the proper domain of public good agricultural science has been further confronted by the new genetic technologies under arrangements that allow companies and individual scientists to recover the costs and capture the profits of germplasm improvement through a range of licensing laws, patents, and Intellectual Property Rights protection

As a consequence of the crises in intensive animal productions, such as BSE[2] (bovine spongiform encephalopathy), or “mad cow disease”, and more recently, the risks of the spread of avian flu, public mistrust has grown since the mid-1990s. Moreover, the new biosciences, and first generation technologies resulting from genomics, also have raised deep public concerns about the increased spread of known allergens, toxins or other harmful compounds; horizontal gene transfer, particularly of antibiotic-resistant genes; and unintended effects (FAO/WHO, 2000). The main consequence for our purpose here is that demand has grown for stronger accountability and publicly funded evaluation systems to determine objectively the benefits and risks of scientific proposals, on a case-by-case approach.

A survey (EU 2001, 2005) of the public image of science as a whole, conducted in 1992 in the EU, showed that 61.2 percent of those interviewed felt that the benefits of science outweighed the negative effects. A re-survey in 2001 showed a steep decline in support, with only a small majority (50.4 percent) of those interviewed agreeing that “The benefits of science are greater than the harmful effects it could have" while about 25 percent held the contrary opinion (EU, 2001: 29).

Mistrust in the agricultural and food sciences also has grown *pari passu* with the increasing concentration of input supply, commodity trade, processing, and retailing in the hands of fewer private companies (Tallontire and Vorley, 2005) and the increasingly dominant role of the private sector as the major financier of development (WRI, UNEP, WBCSD, 2002). The privatization of the scientific knowledge that underpins agricultural modernization is penetrating also the university sector. In the 1950s and 1960s, the university sector was funded largely out of taxes and mandated to pursue public good science for agricultural development. Today an increasing percentage of the funding for university science is being provided by private commercial interests in many industrialized countries. License agreements with universities include a benefit sharing mechanism, which funds research. Product development, especially the trials needed to satisfy regulatory authorities, is expensive and companies need to recover that cost. Private sector interests have required as a condition of funding that they are assigned first patent rights on faculty research results and in some cases the right to restrict publication and the uninhibited exchange of information among scholars. To some extent, there is an assumption that scientific knowledge is more and more a private good, which changes radically the relationships within the scientific community and between that community and its diverse partners.

[2] In the European Union countries, the agri-food industry is most frequently cited as having a large share of responsibility in the mad cow disease problem (74.3 percent). Next are politicians (68.6 percent), farmers (59.1 percent) and scientists (50.6 percent). It appears that many believe that scientists should be encouraged to warn the public (89.0 percent) and, more generally, "scientists ought to communicate their scientific knowledge better" (85.9 percent) (EU, 2001).

### *2.1.4. Technology and innovation processes*

The relationship between technology and innovation has progressively been clarified in past decades, leading to an important broadening of perspective on what needs to be done to foster the effectiveness of AKST. This change in perceptions is important and must be born clearly in mind if one is to understand the debates on technical change, unanimously recognized as a major driver of economic growth and therefore a critical dimension of any assessment of AKST. Briefly stated, from an emphasis on technology the consensus has now shifted to the social processes of innovations. This shift will be explained in the first part of this sub-section; and then the implications for action of this development will be briefly examined.

2.1.4.1 Change in perspective: from technology to Innovations

Economists have long ago identified technical change as a major engine of economic growth, as formulated by Solow (1957). A few years after Solow, another Nobel prize winner, Schultz showed that the transformation of 'traditional agriculture' depended heavily on the contribution of outsiders, bringing new opportunities to traditional peasants. Those peasants were not seen by Schultz as ignorant or tradition-bound but handicapped by severe constraints, which they had very rationally adapted to over time through trials and errors. As a result they could not improve these situations on their own. In that perspective, exogenous technical change appeared then as one of the main hopes for these poor peasants. The green revolution in Asia, which began several years later, appeared as a major vindication of that view. Thus, it is not surprising that Shultz' paradigm quickly became the dominant one in the agricultural economics profession, as illustrated for instance by Mosher (1966), quoted above (subchapter 2.1.2).

That paradigm included also the 'treadmill' process characterized by Cochrane (1958) and based on a perceptive analysis of one major aspect of change in US agriculture, also driven by the dynamics of technical change. In line with neo-classical economics, the treadmill is consistent with the assumptions that farms are basically small firms producing undifferentiated commodities, and that each is too small to affect the commodity price. In these conditions, farmers are price-takers and, in making rational choices, they seek to produce as much and as efficiently as possible against the going price. A new technology that is introduced into this situation leads to a wave of innovations. The first farmers to adopt capture a windfall profit because they can now produce more and at a lower cost than the prevailing price. However, soon others follow and the output price starts to drop. People who have not adopted the new technology see their incomes drop, although they are working as hard as before. They must now also adopt the technology or leave farming. In that sense farmers are like on a treadmill: they must move, i.e. adopt the new technology, but their income does not improve in a lasting manner. Moreover, once on the treadmill, no one can afford to absorb within the farm enterprise the environmental or social costs of the increasing rate of technological intensification. In this manner, very specific market forces operating in agriculture *propel* the diffusion of technologies and the externalization of social and environmental costs. Farmers who cannot keep up with the flow of technical change and cannot withstand the price squeeze, eventually drop out. Larger farms absorb the land, the available capital, and market shares that become available, thereby feeding a process of enlargement of scale or capital invested. One may also note that this process, described at the national level in the case of the USA, explains the growing gap in the productivity of agricultural labor between developed and developing countries, pointed out by Mazoyer and Roudard at the world level, as discussed in subchapter 2.1.1.

Early on sociologists stressed innovations rather than technical change. As already indicated in subchapter 2.1.2, Ryan and Gross's study of the diffusion of hybrid maize in the US Middle West, published in 1943, emphasized the diffusion process in its very title. And this subject became very fashionable among sociologists in many countries for several decades after the end of the 2d World War. Accordingly, Rogers (1983), from a synthesis of a world-wide data-base on the adoption of technology, showed that the likelihood of adoption of any technology could be assessed by means of five attributes: relative advantage compared to technology in use; compatibility (with existing values, past experiences, needs); complexity (negatively related to rate of adoption); trialability (end user can experiment with the technology); observability of results in user's own fields. Others contend that broader institutional and organizational factors largely determine the outcomes even of technologies that satisfy all Roger's criteria, when these are placed into use in different contexts. There appears to be not wholly satisfactory way to sort out the relative contributions of different drivers independent of context. The present consensus is that the inter-relation between technology processes, institutions, and organizational relationships in any situation is irreducibly complex. And this is precisely this complexity which is subsumed under the expression innovation processes.

This consensus has emerged progressively. Once the easy gains of the 'green revolution' in the tropics were made, researchers, extension workers, and input suppliers re-discovered that the heterogeneity in farming systems, in inherent and potential productivity, and in limiting policies and institutional factors must be embraced in order to make further advances in agricultural technology in the small holder rainfed areas (Dixon et al., 2001). It became clear that the wilder expectations inspired by the 'green revolution', of finding a succession of 'one-size-fits-all' technologies that were generally applicable, simply did not exist. Much of what has been written on technology development for enhancing productivity in the 1980s and 1990s in fact refers to baskets of technologies among which 'best bets' could be identified by and for selected farmers in target regions or for target crops. Recently, more emphasis has been given to development of 'best fit' technology options for a given situation, reflecting the re-discovery of institutional and sociological factors that shape technical opportunities (Herdt, 2006; Ojiem et al. , 2006). And actually, this understanding has deep roots in extension research (e.g. Loomis and Beagle, 1950; Röling, Ascroft and Wa Chege, 1976; Ascroft et al., 1973; Petit, 1976), farming systems research (Collinson, Ed. 2000), 1980s gender research (e.g. Staudt and Col, 1991; Sachs, 1996), and 1990s policy research (e.g. Jiggins, ed.1989; Christopolos et al., 2000).

In the meantime, the sets of actors partaking in innovation systems have expanded over time. Initially and still today, farmers have been at the center. Modernity has brought in new actors however, such as state policy-makers, scientists (specialized in specific domains such as genetics, chemistry, biology, human health, and later on ecologists…), inputs suppliers and producers (specialized in pesticides, seeds, fertilizers,…), food processors and distributors in a progressive movement of division of labor. More recently, a new range of actors has emerged, leading to five dominant categories of “agents”: governments, civil society, public research, agrifood science industry, and farmers. Indeed, an increasing body of evidence shows that innovation is a property that emerges from a configuration of interacting actors (Havelock; 1986; Swanson and Peterson, 1989; Röling and Engel, 1991; Bawden and Packham,1993; Engel and Salomon; 1997; Röling and Wagemakers, 1998; Chema et al., 2003; Hall et al.; 2006).

At the same time, the very scientific division between disciplines has been challenged and interdisciplinary approaches of scientific and technological issues have become unavoidable. The ‘innovation systems’ concept is useful to capture this complexity. In the words of Hall (2006): “It has been applied in other sectors, mainly in industry. The concept is considered to have great potential to add value to previous concepts of agricultural research systems and growth by (1) drawing attention to the totality of actors needed for innovation and growth, (2) consolidating the role of the private sector and the importance of interactions within a sector, and (3) emphasizing the outcomes of technology and knowledge generation and adoption rather than the strengthening of research systems and their outputs.”

Accordingly, Hall has been able to propose several key characteristics of innovations.

INSERT BOX 2.1 HERE

In addition, empirical studies have emphasized that the dominant activity in the process is “working with and re-working the stock of knowledge” (Arnold and Bell, 2001). Innovation can be construed as the knowledge process that is triggered by the confrontation with a new object or more broadly by a change in the environment that is not matched by routine and the available stock of knowledge. Innovation can be radical: it then transforms in depth the former situation, or it may be incremental when the innovation process is limited to a specific part of the production system. In any case, this process is a social process that is achieved through interaction and collaboration. It results in individual learning as well as collective learning. Opposite to an invention, focused on knowledge creation, innovation is a process that articulates creation when it exists with ad hoc transformations through the specific, local, individual or collective use of knowledge. As such, innovation is neither science nor technology. Innovation is the emergent property of an action system (Crozier, Friedberg, 1980) in which actors are using science, technology and other kind of knowledge in order to fulfill their individual or collective strategies.

2.1.4.2 Implications for action

The main question emerging from this analysis is how to design interventions meant to stimulate innovations that deliver equitable, environmentally sustainable, and profitable outcomes in the existing mosaic of diverse contexts ? Obviously the history of past innovation processes indicates first that the 'configurations of interacting actors' have to be carefully chosen, relevant to the setting, and not collapsed to unitary and universalizing models. Two sets of considerations, not yet fully discussed, must first be taken into account however in such designs: the importance of market drivers in the innovation processes and the fact that innovations may entail significant risks for societies.

- *Market-driven technology development*

To some considerable extent, innovation processes are being driven by the rise in market-led developments. Figure X-1 illustrates typical responses to market pressures in North America and Europe in terms of the way in which technical requirements, market actors, and market institutions interact (Alexanian, Anderson, Firbank, and Metera, IAASTD NAE sub-global report, 2006).

INSERT FIG. 2.7 HERE

The vertical axis represents the degree of integration, ranging from fragmented markets to high integration with the global economy. The horizontal axis represents the extent of responsiveness to the multiple demands placed on agriculture for goods and services to meet Millennium Development Goals (from reactive to proactive). Actors at the far left respond to economic profit; actors at the far right respond to multiple goals. The blue boxes stand for producers, pink boxes for intermediary organizations, yellow boxes for retail outlets. The small arrows show the most important sources of supply for each sector (and not the complete supply chain). For example, independent grocers get products from vertically-integrated packers, processors and distributors in addition to regional intermediaries. The capitalized products located at the center of the diagram represent typical goods and services produced by each value chain. The size of the arrows indicates the relative strength of the identified trend. The typology locates where most actors within a given sector are at present but actors can move between quadrants. For example, a supermarket chain can adopt Corporate Social Responsibility principles and sell only triple-bottom-line certified goods, in which case it would move to the upper right quadrant IV.  However, most supermarket chains are in the upper left quadrant I at present.

The main trends identified in figure 2.7 are:

Independent farmers are disappearing or going under contract to transnational corporations (TNCs).

Regional infrastructure serving independent farmers is disappearing, or being replaced by vertically-integrated intermediate packing, processing and distribution facilities.

Independent grocers are disappearing or being replaced by supermarkets owned by TNCs.

Large-scale and vertically-integrated producers supplying goods globally are adopting organic methods.

Supermarkets are responding to customer demand for goods differentiated by production practices or locale.  Intermediaries that feed supermarkets are following customer demand for differentiated goods as well.

Some agribusinesses (upper left quadrant) are responding to shareholder pressure and consumer demand by voluntarily adopting Corporate Social Responsibility standards.
As the number of fair-trade intermediaries and retailers increases, they are competing among themselves and cutting corners to make themselves more economically competitive.
Small-scale organic farmers are beginning to adopt other certification schemes, such as social justice standards (partly to differentiate themselves from industrial organic producers).

The NAE sub-global assessment illustrated by figure 2.7 drives home the message that technology alone does not accomplish enough. It is the interaction of technologies and institutions built around specific assumptions and values that give rise to market outcomes that are more, or less, effective in achieving IAASTD goals. This point is illustrated simply in figure 2.8 (adapted from Dorward, Kydd, and Poulton, 1998).

INSERT FIG. 2.8 HERE

The focus in technology-oriented R&D often has been only on developing strong technology (from A to B), as it is now in on-going development of genetically modified crops and animals, or only on developing strong institutions (from A to C), as in the numerous efforts to develop ‘markets’ or specific kinds of market-oriented farmer organizations such as cooperatives. The history of the last decades shows that both approaches fail if implemented on their own. Technology development that aims to be pro-poor, economically viable, and environmentally sustainable needs to focus on pro-active development of technologies and institutions together (i.e. moving within the space from A to D, in figure 2.8). International development policy over the last decade increasingly has favored market-led solutions to the problems of persistent hunger and poverty but the ‘lessons of history’ indicate that powerful market actors in quadrant I, nor technology alone, are sufficient drivers of pro-poor and sustainable development. However, given the goals, not all choices are open: quadrants III and IV of figure 2.7, for example, would appear to drive more clearly toward the desired outcomes.

- *Increasing risks and costs of technology in a globalizing world*

The picture fifty years ago could be described in terms of high local instability in output, a relative autonomy of food systems, and highly diverse local technology options: thus, an agricultural technology that failed in one part of the world, however locally dramatic the consequences, had few consequences for hunger or poverty in other regions. The increase in aggregate food output, and progress toward market liberalization and global trade has smoothed out much of the instability, integrated food markets to an unprecedented extent to the benefit of poor consumers everywhere, and spread successful technologies throughout the world for local adaptation. The mechanisms of food aid, local seed banks, and other institutional innovations have been put in place to cope with catastrophic loss of entitlements to food or localized production shortfalls. Yet the world is faced by outstanding examples of the risks created by these interdependent institutions and technologies (Stiglitz, 2006;

Beck et al., 1994). It seems human beings are not very good at managing complex, systemic interactions (Dörner, 1996).

Examples abound from the mid 1970s onwards of technologies that in use have had negative consequences in given contexts for the poor, or for particular classes or genders, or for the environment; for instance with regard to choices of irrigation technologies (Thomas, 1975; Biggs, 1978; Repetto, 1986); crop management (Repetto, 1985; Loevinsohn, 1987; Kenmore, 1987); natural resource and forestry management (Repetto et al., 1989; Repetto, 1990; Repetto, 1992; Hobden, 1995). The point made time and again by the analyses is that power relations, and the pre-analytic assumptions made about how institutions and organizations actually work in a given context, and where competing claims are made upon resources, influence the way in which scientific information and technologies are developed and used in practice (Hobart, 1994; Hobart (ed) 1994; Alex and Byerlee, 2001). Getting it wrong has had quantifiable costs. The immediate costs typically are carried by the poor, the excluded, and the environment. Feedback mechanisms eventually ensure that the effects impair the sustainability of social and ecological systems on much larger scales.
Analysts recently have pointed to the ways in which public sentiment and policy, especially in countries whose political systems are susceptible to the influence of public opinion and evidence-based policy-making, have begun to compel change in technology use. For instance, the introduction of the Nitrate Directive (1991) and the Water Framework Directive (2000) into the European community entails large scale reduction in nitrate use and fundamental reform of nutrient management practices (Wijnands et al.,1995 for results of Dutch efforts, so far incomplete, to reduce nitrate use in farming systems that over the last 15 years have produced the third highest output by value in the world and some of the worst examples of persistent nitrate pollution; http://slim.ac.open.uk for the effects of the WFD).

An odd but compelling recent example of the risk consequences of ignoring the warning signals of technological failure in given contexts is provided by the near extinction of vultures in India and Nepal (reported in New Scientist, volume 191:2564, p.7). Stories about the disappearance of the vultures were circulating in the public domain in the late 1990s; in 2003 the scientific evidence that a veterinary drug (diclofenac) - widely used throughout the world to treat cattle - was killing vultures was accepted officially. In cultures in which cattle freely roam human settlements, vultures play important roles as scavengers of the dead, and both cattle and vultures act as street cleaners, the need to maintain cattle health as well as to conserve vultures was recognized by policy-makers as important. Yet it took agitation by religious and conservation organizations and three more years before the concerned governments banned the drug. The drug company, Medivet, which was Nepal’s largest manufacturer of diclofenac, subsequently announced it would substitute a safe ‘on the shelf’ alternative, and market it at the same price.

Balancing the relationships among the public interest, markets, science, and technology in a given context, and developing the capacity to make a quicker response to the evidence of ‘surprise’ effects of technology in use, has proven to be a hard challenge. The economic and social sciences have shown that the effective balance often has not served the combined interests of social justice, equity, and the environment, for explainable reasons, but with quantifiable costs.

- *Interventions to favor innovation processes*

Hall (2006) introduces a first factor to differentiate innovation trajectories, claiming for different types of interventions: an orchestrated trajectory and an opportunity-driven trajectory. The first is driven by public actors and policies whereas the second is “pulled” by private actors and markets. Although involvement of actors is different, they both go through development phases, starting from a reduced set of actors and a broad, even fuzzy set of orientations, progressive identification of the innovative set of actions and the widening suggesting the process of problematization and enlistment that is described in the Actor Network Theory (Callon, 1986). The ultimate state is a mature and sustainable system of innovation, enabling the maximum of knowledge sharing between the different domains that it encompasses (fig.2.9). Each step in these trajectories requires different types of intervention (see box 2.2).

INSERT FIG. 2.9 HERE

Finally, to foster the development of innovation systems (Hall, 2006) needs the recognition of the distribution of knowledge in society. It needs to acknowledge the late epistemological revolution (see 2.2.3) that bridges theory and practice and in the same time that blurrs the hierarchy between categories of actors, scientists and end-users or “voicy” groups. Ethically, it needs to acknowledge that the development of new hybrid alliances results in the exclusion of new groups. Politically, the governance of innovation may be seen as a democratic model wherein the contribution of “constantly emerging concerned groups (Callon, 2004)” is facilitated. Hence, good governance of innovation means that the traditional funding of research and extension institutions is not sufficient anymore as the traditional linear model of innovation (research then innovation) has proven obsolete.

INSERT BOX 2.2 HERE

## 2.2 Key Actors, Institutional Arrangements and Drivers

This subchapter will assess the dynamics of past AKST systems in terms of the ways the knowledge and innovation processes have been organized. It will focus on the roles of actors, the dominant institutional arrangements (IAs) and prevailing drivers. IAs are understood basically as the organization of relationships among actors; and the drivers of innovation cannot be meaningfully understood without knowledge of the actors and the IAs (Figure 2.10).

INSERT FIG. 2.10 HERE

This subchapter presents a conceptual framework for assessment of IAs in relation to IAASTD goals, illustrated by relevant examples showing distinctive features. Table 2.3 provides an analytical map, enabling readers to make connections among drivers, broad socio-political and agricultural contexts, production systems and knowledge and innovation processes.

INSERT Table 2.3 HERE

Many actors are involved in the various knowledge processes taking place within agriculture or affecting it. The main actors considered here are in the vast majority *farmers*, many of whom are poor, with limited access to external resources and formal education, but rich in indigenous and local knowledge, and increasingly organized and adept at sharing knowledge and innovating. A*dditional domestic actors* affecting the development and innovation of AKST include local, provincial and national governments, and the agencies, departments and ministries devoted to topics, such as agriculture, environment, education, health, trade, finance. Still *other actors* with direct impacts on AKST include regional consortia and international institutions, such as the Food and Agriculture Organization of United Nations (FAO), the Global Integrated Pest Management (IPM) Facility, the World Bank, the Consultative Group on International Agricultural Research (CGIAR) and others. Each organization brings its own sets of priorities, perspectives and agendas. Regarding key players –such as FAO and the World Bank. and other donor banks, this subchapter will not present them, as the qualitative way in which their roles have evolved is to be illustrated through the thematic narratives (see section 2.3) along the different IAASTD chapters. The private sector, too, has had an important influence on the generation, adoption and distribution of various types of AKST innovations, as have had civil society organizations in addition to farmer-based ones, such as non-governmental organizations, consumer groups and development organizations.

The currently dominant AKST systems are the product of a long history of attempts by diverse combinations of these actors, under numerous IAs, to meet the needs and challenges of agriculture, as well as the actors' own individual or institutional needs. Their histories are made up of some successes, but also failures and frustrations, often leading to new attempts at meeting both local and global challenges. In many instances, these crises have led to the emergence of new actors and the reshuffling of roles and relationships.

IAs can have many purposes, and formally or informally coordinate knowledge producers with or without the input of others. Each IA typically encourages distinct knowledge processes, thus favoring the emergence of different kinds of innovation. Some are permanent arrangements, which developed prior to World War II. Others are *ad hoc* initiatives, or of more recent origin.

The following categories of actors and IAs will be briefly assessed:

- *Farmer and community-based arrangements*
- *National/federal arrangements*
- *International regional arrangements*
- *External actors and international arrangements*
- *Private sector arrangements*
- *Non-governmental organizations and other civil society networks*

Finally, some paragraphs about Capacity Building and Capacity Development will be presented separately, since these terms cut across many of the mentioned categories.

### *2.2.1 Farmer and community-based arrangements*

The emergence of major producer organizations representing their members' interests and rights at district, national, regional and international levels, may be seen as one of the more hopeful drivers of change over the last decades. Most of them are actively engaged in the provision of technology and information services, and have entered into partnerships with R&D providers. Many now have websites that act as an umbrella for, and link to, thousands of farmers' organizations. Examples include the Network of Farmers' Organizations and Agricultural Producers from western Africa (http://www.roppa-ao.org); a multilingual website of the International Land Coalition ( www.landcoalition.org/partners/partact.htm); the International Federation of Agricultural Producers (www.ifap.org); and the website of Peasants Worldwide (www.agro-info.nl/scripts/website.asp), which has links to small producer organizations worldwide.

The focus on the 'local', however, serves to mask the very much wider scale of effort and impact (Boven and Mordhashi, 2002). For example, Catholic Relief Services, just one organization among the many, in 2004 was working directly with 120,000 poor producers in community-based seed system development, impacting many thousands more ( www.crs.org). Other typical examples are provided by the experience of an umbrella organization, South East Asian Regional Initiatives for Community Empowerment (SEARICE) – see 2.2.3 Regional arrangements below. The local seeds movement has given rise also to information exchange networks that seek to assert individual and community rights to 'first publication' so as to safeguard native IPR and plant and other genetic resources. As the movement has matured, organizations of small farmers have strengthened their own R&D networks also through organizing national and international technical conferences – such as the International Farmers' Technical Conference held in conjunction with the 2005 Convention on Bio-Diversity meeting. The collective impact of initiatives such as these is beginning to make a difference as entire regions (such as Styria, in Austria) seek re-assert control over their own food and farming futures. They might be said to represent "zones of heightened autonomy" that buck the trend toward the increasing globalization and concentration of power in the food and farming sectors. In the following paragraphs we will present some of the many initiatives that have brought about changes oriented to the IAASTD goals in the past years:

*Farmer-funded R, D and E and farmer research circles*. Some of these arrangements, e.g. the Philippines protest groups which date back to the 1980s, were born to break the control of local and multinational fertilizer and pesticide companies, multi-lateral institutes and distribution cartels and other issues related to the rice industry. These IAs have the peculiarity of gathering farmers, professors, scientists and researchers together to compose a technical pool of what is then known as a "farmer-scientist partnership." These IAs emphasize the centrality of primary producers in agricultural and food systems. In general, these alliances capitalize on commitments and volunteerism and fund-raising activities to carry out farmer-led projects. They pursue among other things, a holistic approach to development, community empowerment, and people's control over agricultural biodiversity as a contribution in the over-all effort of improving the quality of life of small farmers.

MASIPAG (Farmer-Scientist Partnership for Development, Inc.) was established in the Philippines in 1987, after more than five years' collaboration between farmers concerned about the negative impacts on their livelihoods, local genetic resources, and environment of high-yield rice and associated technologies, and a few progressive scientists. It rapidly developed into a large farmer-led network of people's organizations, NGOs, and scientists, promoting the sustainable use and management of biodiversity through farmers' control of genetic and biological resources, agricultural production and associated knowledge. Their achievements are based on a strategy of placing command of the skills and knowledge of the agronomic sciences in the hands of small farmers. By 2004, the MASIPAG institutional network included four national/regional civil society networks and organizations, seven Philippino universities and research centers, and seven local government authorities and line agencies. MASIPAG's network of trial and research farms included 72 in 16 provinces in the island of Luzon, 60 in 10 provinces in Visayas, and 140 in 14 provinces in Mindanao. MASIPAG today is recognized world-wide as a leading example of highly effective farmer-led and largely farmer-funded and farmer-managed, R, D, andE, that is building small farm modernization, resource conservation, and food sector development on ecological principles (Cfr., www.masipag.org ).

Scientists at Uganda's Agricultural and Animal Production Institute at Namulonge, and local farmers are working to develop and introduce farmer-selected cassava varieties free from mosaic disease. The work is funded by Maendeleo Agricultural Technology Fund and managed by a UK-based NGO FARM-Africa. Agronomic advice and multiplication of disease free varieties is being provided by local farmers' groups, such as the Nakasongala District. In southern Costa Rica. an organized group of small farmers led a common bean breeding program, using a broadly seeded local variety. This landrace had both precocity and acceptable yield, but it failed to resist fungal diseases. The group used a participatory breeding approach, together with researchers from the public research institute, to clean the seed of pathogens.

*Farmer-led education*. These kinds of experience reinforce the lesson that important gains can be won if appropriate investments are made in educating farmers in their occupation as farmers. One of the major breakthroughs of the two decades has been the development and spread of Farmer Field Schools (FFS) as a field-based, experiential learning investment in farmer education (Braun et al., 2005). Based on adult education principles, the schools take groups of farmers through field-based facilitated learning curricula, based on cycles of observation, experimentation, measurement, analysis, peer review, and informed decision-making. The FFS are making in aggregate a significant and influential contribution to sustainable and more equitable small farm modernization, particularly in the rain-fed areas where two-thirds of the world's poor farm households live. Systematic review of available impact data (van den Berg and Jiggins, 2007; Braun et al., 2006) and area-based impact studies (Mancini, 2006) demonstrate strongly positive potential. By contributing effectively to farmer empowerment they also are contributing to the strengthening of civic society and self-directed development (Mancini et al. 2007). Other case studies, however, have criticized their cost in relation to the scale of impact (Feder et al., 2004a; 2004b), or the lack of diffusion of curriculum elements (Rola et al., 2002) and failure to develop enduring farmer organizations (Tripp et al., 2005). Van Mele and Salahuddin (2005) suggest further experimentation is warranted to test how, by combining farmer education such as the FFS offer with complementary extension effort, the perceived shortcomings might be overcome.

The FFS form part of wider effort to offer farmers, both men and women, relevant opportunities for learning how, when and why to make more expert decisions, in ways that address the place-dependent and time-specific management and technology needs of agro-ecological development at farm and landscape scales, and of sustainable rural livelihoods. These initiatives all see added value in working with indigenous knowledge processes rather than seeking to over-ride them (Coutts et al., 2005). For instance, World Learning for International Development, Alaska Rural Systemic Initiative project, and the Global Fund for Children have documented the gains in the effectiveness and efficiency of science education and in the development of agro-ecological literacy at the grass roots of such approaches (summarized in IK Notes No. 87, 2005).

*Local/indigenous actors*. Subchapters 2.1 and 2.2 have made it clear those indigenous/local actors (farmers and communities) and their arrangements play a key role in this historical analysis and assessment. Research on indigenous knowledge indicates that farmers can be informed innovators (subchapter 2.1.5). Some additional examples are mentioned below

In the village of Wenteng, southwest China, women expert maize breeders control the breeding process, from field design to seed selection through pollination in a combined program of formal-led and farmer-led research (Song and Jiggins, 2002). Traditional plant varieties are maintained through generations by separating the planting of different varieties in space and time. Women farmers also acquired maintained and refreshed varieties through open pollination hybridization. Another example of systematic testing of user involvement in the breeding cycle is given by a formal-led PPB project for barley in Syria (Ceccarelli et al., 2000). The researchers began by designing four types of trials: by farmers in their fields, with farmers on-station, by breeders in farmers' fields and by breeders on-station. Their experience of the rigor, reliability, and comparative costs and benefits of the four led them to concentrate on testing and selection by farmers in their own fields, complemented by seed multiplication on station. There are also many examples, coming from different areas, of other kinds of effective technological advances pioneered by farmers, such as the use of grafting against pests and the use of biological control agents, or the golden ant in citrus in Bhutan (Van Schoubroek, 1999), or soil management and farming system development in Adja Plateau, Benin (Brouwers, 1993).The value of local and indigenous innovations have not been much researched. One study in Nigeria estimated the value of the contribution of the informal agricultural sector, where farmers are using mostly indigenous innovations; it totals some US $12 billion per year, providing income for an estimated 81 million people (ECA, 1992; Nwokeabia, 2006). This estimate, however, does not include the cost of opportunities foregone or indigenous practices that do not work. Recent literature begins to sketch out the strengths and weaknesses that might be taken into account if a more comprehensive analysis were to be attempted (e.g. for farmers' seed production, cfr. Almekinders and Louwaars, 1999).

#### *2.2.2 National/federal arrangements*

Countries have a complex array of public institutions, IAs and actors responsible for planning, funding, carrying out, assessing and disseminating agricultural research. Comprehensive economic data of rigorous quality are much more widely available for these kinds of arrangements. They include actors, such as national/federal, regional/municipal agricultural research institutions, universities and other higher education institutes and extension services. Most of them have historically been publicly financed, since agricultural research demands lumpy investments, involves externalities, and is subject to long gestation lags (Lele and Goldsmith, 1986). Thus agricultural research since the mid 1880s until recently has almost everywhere been conducted mainly by government research organizations; as noted earlier, they currently are facing severe budgetary restrictions in many countries and have been reducing their key role. Nonetheless, according to Pray and Umali-Deininger (1998), the public sector still finances about 90 percent of total agricultural research in developing countries, and about half in industrialized ones.

As mentioned in 2.1, in the 1960s and 70s, the National Agricultural Research System (NARS), especially the Institutes for Agricultural Research, received strong financial support from government and international donors to launch the agricultural modernization through the dissemination of the new technologies developed from the Green Revolution. In the 1980s, as a result of the crisis and adjustment programs, public funds for agricultural research did not keep up with expanding demand. Public expenditure declined as proportion of total research and development spending, but the expenditure per researcher declined much more because staffing continued to expand faster than budgets. Since the 1980s, structural reforms and adjustment policies, major global political changes, increasing demands for reduced public sector involvement and intervention, a more private sector role, scarcity of resources for agricultural research, significant biotechnological breakthroughs, and institutional developments have given shape to the present NARS panorama.

*The sub-Saharan National Research System*. The overall budget constraints tend to paint a gloomy picture of the state of public sector NARS. The general panorama is of deep and probably irreversible attrition of human resources, equipment and facilities, funding and revenue. The non-governmental organizations, consultative groups, and private commercial sectors, and recently the establishment of the sub-regional bodies, Central African Council for Agricultural Research and Development (CORAF), Association for Strengthening of Agricultural Research in Eastern and Central Africa (ASARECA), etc. supported by the Forum for Agricultural Research in Africa (FARA), have filled the gaps only in part. Besides, privatization of research so far has proven unhelpful, e.g., the agricultural research trust funds set up to lever matching support from commercial, donor, and government organizations, have not succeeded. Yet, there are some green shoots emerging at local levels, as the centralized research establishments disappeared, showing how demand from farmer-managed funds, which can be allocated among a range of research providers, can increase relevance and uptake (Table 2.4).

INSERT TABLE 2.4 HERE

*The Agricultural Research Council (ARC) model*. Some large countries, with complex research systems have established agricultural research councils to coordinate the work carried out at research institutes. The ARC is a public body which has – *inter alia*- the functions of managing, coordinating or funding research programs. Managing councils have proved effective because they have autonomy for planning and executing research, whereas coordinating councils simply coordinate and lack resources and administrative powers, although in some cases they have moved beyond a policy and coordinating role to undertake research themselves. Funding councils influence prioritization and fund allocation of research, but they do not catalyze it. In all cases, however, it is becoming increasingly clear that national agricultural research may not be as well served by such bodies as was intended. Particularly in Africa and Asia, where a number of agricultural research councils have been created—often with considerable external support—they have (with some notable exceptions) to some extent failed to live up to expectations. Instead of streamlining research, avoiding duplication, and guiding the system with strategy and vision, they have sometimes become an additional bureaucratic layer that may hamper, rather than facilitate, effective technology generation and dissemination.

*The National Agricultural Research Institute (NARI) model*. This model is common in Latin American countries, where agricultural research has been conducted mainly at national level. National institutes enjoy great freedom. They control, direct and manage all publicly funded agricultural research; they may be autonomous or semiautonomous in budgetary support, scientist recruitment, financial norms and disciplines with experiment stations as the basis for research organization. Their size and organizational pattern vary from country to country. Most NARIs were created in the 1950s and early 1960s, many from centralized units of agricultural research under the ministries or departments of agriculture. Their creation was driven mainly by the recognition of the leading role of technological change in the modernization of agriculture. In some cases, R&D activities were integrated very closely with rural development efforts and were effective tools in the fight against poverty. In the late 1990s, NARI-based models showed a clear trend to differentiate rural development and poverty alleviation efforts from research and technology development, which was accompanied by an increasing participation by private sector entities in financing and implementing R&D activities. These changes stem from the transformation of the socioeconomic and political context within which R&D systems operate (i.e., state reform, deregulation, economic liberalization), as well as changes in the nature of the scientific process underlying agricultural research (i.e., privatization of knowledge, plant breeders´ rights, patent protection for R&D results, etc).

Two important constraints have limited the role of the NARIs in Latin America: the decline in agricultural research funding and the relatively low coordination and cooperation among research system components within each country. In many cases, each tends to work in isolation from others, in part because mechanisms to promote cooperative programs and projects are lacking. The result is a less efficient allocation of scarce research resources. The National Institute of Agriculture (INTA), Argentina, and the National Institute of Agriculture (INIA), Chile, both have responsibility for extension. INTA created in 2005 a Center for Research and Technological Development for smallholder family agriculture (CIPAF), with three regional institutes, thus shifting from the traditional Transference of Technology (TOT) Model that characterizes NARI, to a participatory action-research approach. This methodology warrants small farmers' commitment to research and leads to socially pertinent and sustainable programs. Since 2003, Brazil has promoted a national policy based on biotechnology and allocated funds for biotechnological innovations in agriculture. The Brazilian Agriculture and Livestock Research Company (EMBRAPA) has worked intensively to expand research and technological development in the area of family agriculture, further encouraging improved productivity. It is collaborating in the federal government *Fome Zero* (Zero Hunger) program, whose cornerstone is to win the battle against hunger. EMBRAPA is also taking part in the Cassava Biotechnology Net (CBN), through the Biotechnology Research Unit of *Mandioca e Fruticultura* (http://www.cnpmf.embrapa.br) and the Participatory Plant Breeding Group of EMBRAPA-CNPMF, Cruz das Almas, Bahia, together with the Bahian Company of Agricultural Development (http://www.ebda.ba.gov.br), Caetité, southeast Bahia and farmer communities also located at Caetité.

*The Ministry of Agriculture (MOA) model.* This model prevails in countries with small-sized agricultural research arrangements. This system has centralized governance and sometimes is bureaucratic in practice. However, in recent years new organizational patterns have emerged providing more flexibility. It was also the dominant model in LA countries before NARIs were established.

*Universities and other higher education models.* Burton Clark (1983) has depicted universities as institutions placed amidst three coordinating forces: the academic oligarchy, the state and the market. Undoubtedly, in the *Humboldtian* model prevailed the academic oligarchy, with not much room for the state and the market. The former Soviet Union university illustrates the state predominance with no room for the market, and only a limited role for the academic oligarchy in decision-making, while the private university in the United States had very little government interference, but took due notice of market demands (Clark, 1983). These three forces are seldom in balance, but rather in a continuous and dynamic tension which often brings about conflicts and ruptures in the university realm. The role of university leaders is to cope with these forces and in one way to hold the state at some distance, in order to defend university autonomy and creativity -which are the *raison d'être of t*he institution (Busch *et al*., 2004)- but keep it satisfied in order not to interrupt funding; at the same time to comply with market forces, without letting them meddle in teaching or research programs, and on top of that to keep academics motivated, even when money is scarce. These forces create fields of conflicting powers within universities (Bourdieu, 1988), give way to diffuse and often contradictory missions -not always shared or even perceived by main actors (Busch *et al.* 2004)- and model them as loosely coupled structures. Weick (1976) defined this kind of organization as that in which components are responsive to a certain extent, but retain evidence of separateness and identity.

There are three principles and associated practices that stand at the center of contemporary universities: creativity, autonomy and diversity (Busch et al., 2004). Universities can only be successful if they further creativity among their faculty, students, and staff. Anyway, without substantial autonomy, scholarly work may become subject to political or market-driven whims. A diversity of standpoints is essential to the debate and dialogue that must be central to universities. These authors emphasize that these principles enable the university to generate knowledge, inventions, and innovations, to translate and disseminate knowledge in ways that foster the growth and development of people and communities, and to contribute to discourse about social issues.

In agricultural universities (schools/colleges or faculties) there are divides and conflicts, among missions, between social and scientific power, among managing, teaching, researching and extension, between the established canonical disciplines for agricultural studies, and the newer “marginal” disciplines, such as sociology, ethics, administration, etc. These divides give way to different tribes and territories (Becher and Trowler, 2001), with established rules, frontiers, *enclaves*, non-trespassing sites and a few bridges. Universities are undoubtedly and necessarily-since they express social distinctive traits- tension-filled places (Readings, 1996; Delanty, 2001). This is not a bad thing in itself, but creates a need for revitalizing social debates and institutionalized discussion of its missions and societal responsibilities in view of the urgent demands posed by hunger, poverty, inequality, exclusion and solitude.

Universities have been profusely cited as key actors in national research systems (Castells 1993; Clark 1995; Edquist 1997; Mowery and Sampat, 2004). However, their contribution to agricultural research, real or potential, is often neglected. Yet, according to Atchoarena and Gasperini (2002), universities can educate the professionals and technicians to promote sustainable agriculture practices and accompany the process of rural development, provide continuing education for thousands, become the voice of reason and factual information in controversial debates about bioethics, transgenic seeds, intellectual property rights, food quality and safety issues, etc. They can also develop teaching capacities in the educational system and become a visible lobbying force for comprehensive education for rural development through clear and logical arguments, supported with indisputable data.

Despite the fact that they have mobilized cross-border flows of knowledge and people since medieval times, universities retain strong national characteristics and structures across space and time. These structural contrasts are the result of long, path-dependent processes of historical development, in which institutional evolution has interacted with industrial growth and change, as well as with socio-political issues.

There are at least three different types of agricultural higher education institutions: (i) agricultural schools, faculties or colleges, embedded in a comprehensive-university, (ii) landgrant universities, patterned after the US landgrant universities, and (iii) the tertiary level agro-technological institutes, which are not part of a university and depend on a ministry or secretary of education or agriculture. These institutions are not *ad hoc* research arrangements, but have other mandates, mainly teaching and extension, and they all have similar constraints to achieve the diversity of their roles and purposes (Table 2.5).

INSERT TABLE 2.5 HERE

(i) *Agricultural schools or college/faculties model embedded in a comprehensive-university.* This model is shaped after the German *Humboldtian* model (1809), which has teaching and research as central functions. This university encompasses now a third mission, extension, and has irradiated to different parts of the world, mainly to the Americas. In general, the original unit pivoted around the law, philosophy and medicine school. Agricultural science programs joined later. In most cases, they were transferred from the Ministries of Agriculture, becoming part of a comprehensive-university as agricultural colleges, schools, or faculties.

In many countries, research universities are academically autonomous institutions. Public funds are provided as block grants by the Treasury to the Ministry of Education, which transfers them to the central university governing body. University allocates these funds across departments or colleges according to different criteria. Only then they reach agricultural colleges to finance their activities. In Latin American countries, research budgets are often less that 0.5 percent of the total university budget (FAO, 1993; Gentili, 2001) However, in the last decades research has also been financed by the use of competitive funds open to public research institutions and in some cases to private universities. International donors and national foundations also contribute to financing and in some cases-although not as frequent as in developed countries- sectoral private actors play a significant role.

In general, agricultural research colleges have much prestige based on teaching and research, which have relatively high standards ( Their main asset is research, and their internal system of reward and promotion lies heavily on the “publish or perish” system, no matter how constrained their budgets are in developing countries. This system –imported from industrialized nations- also further increases the gap between developed and developing countries’ national academic and research systems. It also further marginalizes scientists and academics in the latter countries where funds for research, in particular for basic research, are scarce. The divide induced by the “perish or publish” system also relegates basic research from applied research. University research teams do basic and strategic research at the researcher's initiative on the general university funds and perform applied research sometimes with outside financing sources under different agreements. They have to fulfill their triple mission and at the same time have acceptable research standards under generalized attrition of funding, which means low salaries, lack of equipment and infrastructure, reduced library subscription to leading journals, less opportunities to study postgraduate programs in the most advanced scientific centers, etc.

In addition, research has gone in new ways, with new actors and funding for old, "researched-out" areas, diminished.  This results in scientists' brain drain to developed countries and private companies and turnover of academic staff, jeopardizing the three programs. Nowadays, these colleges are seeking different sources of funding support through strategies of commercializing research products and services, applying intellectual property protection. Anyway, many have a *caveat* to this issue, since there are limits concerning public goods, which by definition cannot be commercialized (Byerlee et Alex, 1998).

The most immediate challenge these institutions have to face is how to become more involved with community needs and be able to solve real agricultural problems and developing community capacity. Problem solving in participative processes implies working with poor farmers rather than for other segments of society. Therefore, agricultural colleges need to open themselves to society and mobilize knowledge, skills, and expertise through an outreach structure that is capable of providing external linkages from university to community and back to university. As this type of university arrangements is frequently isolated from experiment stations or has weak links with them, it is rather hard for them to fulfill extension goals without establishing nets. Their extension is too frequently carried out as separate programs, not embodied in a unified effort of research and education. In addition, research and teaching programs suffer from the lack of contact with extension activities which may provide them real agricultural problem inputs. Obviously, this need for linkage to extension depends on the type of research carried out at the university. For example, the search through the world collection for a gene linked to disease resistance, the structure of a protein relevant in photosynthesis and whether silicon is an essential plant nutrient are examples of research about which extension people should have awareness but which are not extendable to farmers.

Many of these institutions need to establish or increase linkages and robust alliances with (i) farmers - men and women- as well as with cooperatives and farmers' organizations through farmer participatory research and knowledge management systems, (ii) government extension, credit and development agencies, as well as with private sector companies dealing with seeds, fertilizers and other essential inputs, (iii) other NARS institutions, private universities, international donors, etc..

(ii) *Land-grant colleges and state universities.* They have been patterned after the US land-grant model originated in the 19th Century.  The mission of these institutions was to teach agriculture, military tactics, and the mechanic arts as well as classical studies (first Morrill Act, 1862). The first Act provided grants in the form of federal lands to each state for the establishment of a public institution to fulfill the act provisions. A key component of the land grant system concerning agriculture is the agricultural experiment station program created by the Hatch Act (1887), which authorized direct payment of federal funds to each state to establish stations linked with the land grant institution. Despite land-grant universities in the US today may not be significantly different from other kinds of universities; the model was taken to different countries and its main characteristics- democratic access to knowledge, pragmatic and experimental view in research, and closeness to regional and local production through outreach activities- flourished in remote countries. After World War II, the Rockefeller and Ford Foundations, and the United States Agency for International Development (USAID) played critical roles in the establishment of state agricultural universities in India, which had a similar conception to the American model. State agricultural universities of Pakistan and the Philippines are also based on this model. They are autonomous organizations, with state-wide responsibility for teaching and research. The responsibility for extension activities rests with the departments of agriculture and of animal husbandry, which depend on the Ministry of Agriculture. The agricultural universities receive core funds for research and education from the state governments and grants from other national institutes.

In sub-Saharan Africa, the research and extension missions of the land-grant model generally introduced under ministries of higher education came into conflict with research and extension departments in ministries of agriculture, and by the eighties, most of the land-grant universities became comprehensive universities, with emphasis on training. In the process of land-grant transplantation much was lost; notably, the elements that ensured the structural and financial accountability to farmers. In some cases, their model changed into central- and state-funded institutions for producing graduates with the result that effective service and outreach to small-scale farmers and farmer control over university agendas and outputs weakened and then virtually disappeared with funding cuts and changing ideologies.

Nevertheless, the model proved powerful; land-grant universities in the USA throughout the 20th century have been central to America's farm modernization, dominance in commodity trade, and pre-eminence in global food industries (Ferleger and Lazoncik, 1994; Slaybaugh, 1996; Fitzgerald, 2003) This construct explicitly rests on: concern for both agriculture and rural communities; enterprise development and revenue and welfare; education and research as a privileged knowledge and information activity for faculty and students and as a service to people's needs. The task of forming, educating and empowering farmers and young farm leaders has been seen as a key strategic objective and rests on tripartite funding contributions: from education, agriculture and state agencies at various levels. Farmers hence have an opportunity, as well as right, to participate in forming and assessing university research priorities and outputs. Outreach and service count in professional advancement; and the universities' own institutional advancement - even survival – rests on accountability to the broad constituency it serves.

*Universities and other national IAs*. In Latin America, Argentina's national public universities have been patterned after the *Humboldtian* model, encompassing now teaching, research and extension mandates. Agricultural faculties (schools) are embedded in comprehensive universities, and have academic and institutional autonomy. Agricultural research is conducted mainly by the universities, the National Institute of Agricultural Technology (INTA), the National Council for Science and Technology (CONICET) and private companies. This has resulted in a somewhat fragmented system, with weak links among IAs. The vast capacities of agricultural faculties have been neglected by policy-makers and are poorly mobilized to become part of the general agriculture R&D policies. Overall, universities represent an underutilized resource that can increase the total research output of the country with medium levels of funding, since they already have significant human resources in place. However, as they rely too much on competitive funding, they may not be able to develop long-term research programs due to the lack of funds for research facilities and infrastructure, the ephemeral nature of grants, and the uncertainty of funding continuity.

It is difficult to develop a robust indicator system to assess university efficiency and effectiveness. In some cases reliable proxies have to be identified. Oesterheld et al. (2002) analyzed journal publications from Argentine agricultural scientists for the period 1996 to 1998 from different institutions. On the basis of number of journal papers pondered by the impact factor (Institute of Scientific Information) the contribution of these scientists to internationally-cited journals was measured. The authors found that it was highly variable and on average, low. However, agricultural university output was higher than the other institutions, despite their financial resources were scarcer at that moment.

(iii) Higher education agro-technical institutes. They are post-secondary agro-technical institutes (tertiary level) that are not part of the university system. They usually depend on ministries of education, science and technology, or ministries of agriculture. They have less academic autonomy than university colleges/schools or faculties and mostly train technicians in agricultural competences related to regional and local labor demand.

These institutes are oriented to bridge the gap between non-trained farmers or semi-skilled resources, and fully qualified university graduates with 3-5 year-degree programs. Over the past decades, many developing countries have neglected the training of technicians and technologists, and middle management resources of different industries. Coupled with diminished training was a labor market distortion of under-employing highly trained professionals and the consequent brain drain to more developed countries.

In general, research is not well organized and developed within these institutes and is mostly directed to satisfy local needs with applied technology. Links among research and extension are weak and the main focus is on resource training. They offer short-term programs and have close alliances with the private sector with which they sometimes integrate regional clusters. They interpret regional and local needs better than metropolitan universities and are closer to sectoral groups, farmer associations and cooperatives. They have the mandate of providing the regional and local demand with agro-technical and entrepreneurial cross-cutting competences, which are the bedrock for sectoral small- and medium-scale enterprises.

Agrotechnicians have a wide range of practical farming skills and understand the main issues facing the world of agriculture, as well as their responsibilities and roles as farmers and agribusiness operators for dairying, cropping/grazing, poultry, pigsty, food packing, and horticulture industries. Employment can be found as technical assistants, operating agricultural businesses, providing advice to farmers and in areas such as extension, rural tourism, landscape and rural journalism.
In some countries, as in Brazil, the agro-technical CEFETs, or Federal Centers of Technological Education, originated in agro-technical or vocational schools (secondary level), which competed for grant allocations, mainly form the Ministry of Education and international donors, and upgraded to the status of tertiary-level institutes in the mid-nineties.

They have good links with the private sector and sometimes share resource training activities through “sandwich courses,” etc... These courses are drivers for the technological application of new and old technologies, and technologies appropriated to solve problems of a certain community, so that negative effects for the environment, society, economic and cultural aspects of the region are minimized.

Separate management of these institutes (by the Ministry of Agriculture or the Ministry of Education) divides rather than unites the different national education and extension programs and isolates them from universities. There are only a few examples where bridging can be made between university and non-university tertiary levels. According to Atchoarena and Gasperini (2002), an extension worker with secondary education and a two year agriculture certificate – from a tertiary level institute- plus considerable field experience can seldom bridge to a degree program. An exception to this phenomenon is the Sasakawa Africa Fund for Extension Education program (SAFE) (Naibakelao, 2000).

Finally, agricultural technical or vocational schools (secondary level) have also played a relevant role in generating local knowledge in close relationship with family agriculture and territory development. In many cases they represent the only link with society rural families have in inaccessible places. Many countries have chosen the «*alternance*» agrotechnical school system shaped after the French rural movement of *Maison Familiale Rurale* (rural family house) started by the Abbé Granereau in Serignac-Peboudou (1937). Through this modality, students have an alternate training system at school (where they also live for some time) and then at home, in their family smallholding. This system has disseminated all over the world.

*Unraveling the university dilemma*. University institutions were called on to fulfill the same research mission as other national arrangements. However, they also teach and provide extension services. Teaching not grounded in research and without connection with the real world is vain; research not applied and transferred to real world problems is worthless; outreach not informed by research and

pedagogical skills is ineffective (Derek 1982, Boyer 1990). In other words, the university resembles a juggler trying to keep three balls up in the air. Sometimes it does not achieve the goals with equal quality, bringing about internal conflicts. Universities have finite resources and limited expertise and need resources, updating, further specialization and replenishing of their knowledge-base. Besides, due to faculty organization and career, universities will always be short of funds, since if their funds are plentiful in a new area, faculty will expand there while honoring tenure in the old areas, but with less support, as faculty gradually ages and retires.
Universities hold immense potential as powerful drivers to reduce hunger and poverty, improve rural dwellings and facilitate equitable, environmentally, socially and economically sustainable development. However, their ongoing struggles for funds and lack of policies have undermined their capacity to play a role as a key actor, and hence they have often been neglected by national policy makers.

*Public-private arrangements*. The Foundation for the Participatory and Sustainable Development of the Small Farmers of Colombia (in Spanish, PBA) was created as a nonprofit organization whose main objective is to contribute to the improvement of the living standard and to overcome the poverty conditions of the small farmers in Colombia, based on the development and application of sustainable technologies. Its members are Colombian public entities, such as the Ministry of Agriculture and Rural Development, the Ministry of the Environment and the DNP (National Planning Department); international research centers, such as CIAT (International Center for Tropical Agriculture); mixed research Colombian agencies, such as CORPOICA (Colombian Corporation of Agricultural Research) and CONIF (National Agency for Forestry Research); important national and regional universities, e.g., National University, Cordoba University and Sucre University and local participative groups as well as other organizations of small farmers.

Small farmers are the soul of the Foundation and have an active role in all its phases and aspects, starting with the determination of the problems that they want to overcome, until the follow up and assessment of the different programs and projects. In the zones where the Foundation works, the small farmers are organized in local participatory groups (LPGs) or other kind of associations, which are responsible for carrying out the research, development and training activities within their own locations. They are also in charge for the promotion and the creation of small farmers' enterprises that produce clean seed and biological and organic inputs – Technology Based Enterprises (TBEs) – and associative enterprises for crops transformation and commercialization. Women have an outstanding participation in these enterprises.

*The Andean Consortium*. The Andean consortium has emerged over the last fifteen years by building on the scientific strength-in-depth, leadership and management capacity of its member organizations. It has a strong participation from farmer organizations and farmer-scientist collaboration in research. By initiative of the *Corporación para el Desarrollo Participativo y Sostenible de los Pequeños Agricultores* (PBA) – a Colombian foundation- the five Andean countries (Venezuela, Colombia, Ecuador, Peru and Bolivia) developed a regional project with the purpose of "introducing innovations

with small farmers" of the Andean Region through the development, adaptation and exchange of technologies and participative, sustainable methodologies that contribute to improve their quality of life." The purpose of this initiative is not only to strengthen the regional links in terms of participative research exchange with small farmers in sustainable agriculture, but to begin a larger regional cooperation process aiming to establish an Andean Consortium for participative innovation with small farmers and to access to new international technical cooperation and financial sources.
The project has achieved significant advances on the characterization of small farmer's economy, on the establishment of the participatory research nucleus, on the building of the infrastructures for participative research activities, as well as on the preparation of documents summarizing their experience on clean seed and bio-inputs production and methodologies and strategies of participative research, empowerment and entrepreneurial organization of the small farmers.

The PBA Foundation prepared the proposal for the "Participative Innovation Program with Small Farmers in the Andean Region", approved by the Nederland's Government in 2005, aiming at improving the level and quality of life of the small farmers in the Andean Countries based on participative innovation processes, on the sustainable use of agro–biodiversity, the exchange of experiences and training through the creation and consolidation of an Andean Consortium of Participative Innovation. The Foundation has been concerned at the establishment of alliances, agreements, and collaborative work that provide knowledge and skills to farmers. Thus, the Foundation is carrying out cooperation activities with universities, cooperation centers, research institutes, networks and programs.
Small farmers have effectively adopted the Foundation programs -which they consider their own. The main empowerment strategies used by the PBA are:

- A wide participation of small farmers in the program and project design, implementation, follow up and assessment
- Intensive training in four main knowledge areas: technology and methodology, environment, organizational/entrepreneurial issues and personal growth.

According to PBA, in agricultural production competitiveness and sustainability issues reinforce each other: without an income-generating competitive, small farmers end up cutting trees, and overexploiting the fauna and the flora,  as well as other natural resources. Without a sustainable strategy, they will not be able to be competitive or profitable at the medium or long term, because of resource degradation. Besides, the lack of competitive and sustainable production can force them to migrate to other zones seeking non-legal profitable alternatives.

### *2.2.3 International regional arrangements*

International regional IAs are heterogeneous. They deal with different issues and have network based approaches, diverse mandates, governance, statutory objectives and regulations. IAs may occur through formal or top-down, state-driven mechanisms or collaborative bottom-up induced processes.

Regional arrangements have the potentiality to lead to "tailor-made" regional solutions and a better use of collective capacity. Many issues, such as watershed management, forest fires, insects and diseases, conservation, etc., can be addressed more effectively regionally than at national levels. Therefore developing countries can pool resources jointly that would otherwise be too costly to afford. They can also create synergism by sharing information, experience and expertise. Besides, regional groups can carry more political weight than individual countries and develop positions *vis-à-vis* international instruments. Their overarching strategy for the future may be to prevent extreme divergence, reduce overlap and enhance convergence of regional processes.

*Southeast Asia Initiatives.* South East Asian Regional Initiatives for Community Empowerment (SEARICE) is based in the Philippines and dates back to 1983 (cfr. http://www.searice.org.ph/). SEARICE has served as the secretariat for region-wide advocacy, lobbying, and civic actions among networks of civil society organizations to prevent national and international IPR legislation from restricting farmers' seed exchanges and sales, and to ensure legal recognition of farmer-bred varieties and of community registries of local plants, animals, birds, trees, and micro-organisms. SEARICE typically works with consortia led by civil society organizations, including local, national and international NGO networks, national research institutes, and local extension and advisory services. It has assisted in the establishment of community-based native seeds research centers, such as CONSERVE in the Philippines, Farmer Field Schools for Plant Genetic Resource Conservation Development and Use in Laos, Bhutan, Vietnam, and community biodiversity conservation efforts in Vietnam, Thailand, and the Philippines.

*Mekong River Commission.* The Mekong River Commission was founded in 1995 by the "Agreement on The Cooperation for the Sustainable Development of the Mekong River Basin" (cfr. http://www.mrcmekong.org/). Four downstream riparian states (Cambodia, Laos, Thailand, Vietnam) cooperate to achieve a prosperous, socially just and environmentally sound Mekong River Basin. Thus, the countries promote and coordinate sustainable management and development of water and related resources (e.g., forests), by implementing strategic programs and activities. Therefore, they intend to strengthen the links among agriculture, irrigation and forestry, as well as research on the best methods for monitoring land use changes and baseline studies on watershed management, forestry and land use planning.

*Sub-Saharan African Initiatives*. In SSA, the emergence of regional arrangements has been prompted by two, somewhat contradictory, trends. On one hand, many countries have failed to fund and support their own agricultural R&D capacity and these have atrophied steadily as donors lost interest institutional development on the back of project-based funding in the absence of evidence of substantial state commitments. On the other hand, the countries that have bucked this trend (such as Kenya, South Africa, Senegal, Benin) have seen their NARIs emerge as regional service centers. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASERECA) is building on the strength principally of the NARIs in Uganda, Kenya, and Tanzania. It is providing training and capacity development services throughout the region, thereby helping actors in the national and sub-national R&D arrangements to become capable of bidding on local and international competitive research funding in partnership with a range of public, commercial, and farmer- or community-led organizations. In southern Africa, formalization of inter-state collaboration on agricultural R&D has not yet occurred. The South African Agricultural Research Council and universities continue to provide a region wide back up service, and various R&D networks seek to fill some of the severe gaps in public and private capacity that have emerged. In West Africa, the Central African Council for Agricultural Research and Development (CORAF) is facilitating networking across the francophone-anglophone divide, helping francophone countries to build capacity whilst easing some of their dependence on metropolitan institutes overseas, and lobbying hard to persuade the region's governments of the high returns to investment in agricultural R&D, in terms of the Millennium Development Goals and the New Partnership for Africa's Development Goals. The Forum for Agricultural Research in Africa (FARA) is the apex organization of these regional arrangements, with a strong focus on strategic priority setting, institutional innovation and capacity development, and advocacy.

Given the fragility, even in the better performing NARIs, of institutional R&D, the regional and pan-African arrangements are considered inevitable. How capable they will prove in bringing about policy reform, organizational innovation, and an upturn in capacity remains to be seen (cfr. NERICA initiative in subchapter 2.1).

### *2.2.4 External actors and international arrangements*

*Agricultural research and development during the colonial period*. As evident from the preceding discussion, farmers and many other local and national actors have participated in agricultural activities, including research, development, extension and education, in formal or informal processes, for many thousand of years. During the 19th century, a new set of external actors and IAs –often in the form of colonial regimes- intervened in many of the world's tropical agricultural systems. A primary objective of agricultural research and development in these colonies was to provide the ruling colonial powers with cheap and abundant supplies of foods, beverages and industrial raw materials. Colonial era production goals were frequently achieved through plantation-style agriculture, underpinned by a mixture of social and economic incentives and coercive control of farm workers.

Thus in this case, the IAs for AKST were fairly simple: a relatively small, specialized research institution, focusing on one crop, employing a relatively small number of well trained scientists, providing them with adequate facilities and equipment and judging their performance on their abilities to deliver what they consider to be appropriate packages of technologies (ref).In addition, the main colonial empires (UK, France, the Netherlands, Belgium) created and maintained research institutions of a more academic nature, but often multidisciplinary, in charge of accumulating knowledge on the colonial territories: their natural resources, their populations, etc. As a result, an institution such as the *Institut de Recherche pour le Développement (ex-ORSTOM)* in France, may perhaps be today the largest source of knowledge on the diversity of ecological and ethnic situations in Africa.

These colonial systems of AKST were generally effective for their purposes, but they badly neglected the food crops consumed by the 'indigenous' populations, with a few exceptions, e.g. the federal research station for French West Africa created in 1935 and the emphasis given to increased food production just after the second World War (Benoît-Cattin, 1991). This neglect of subsistence crops led to the creation of the International Agricultural Research Centers (IARCs) and subsequently, the CGIAR.

*Consultative Groups on International Agricultural Research (CGIARs).*

The role of the two US based foundations, Rockefeller and Ford, in the creation of the first international centers has been well-documented (Baum, 1998). The first international research center (CIMMYT) was devoted to wheat and maize, the second one – the International Rice Research Institute (IRRI) established in the Philippines in 1960- was devoted to rice. Rice, wheat and maize are the three major cereals providing the bulk of basic food production in developing countries.

The emergence of this new type of institutional configuration had a profound impact on the IAs for agricultural research in developing countries. In this respect, the rapid evolution of the role of IRRI is exemplary. The first high-yielding (HY) rice cultivar released by IRRI (IR8) grew out of a dwarf gene which originated in Japan. Soon, however, its limitations became obvious. The new variety was sensitive to multiple pests and did not have the taste desired by many in Asia. The second generation of HY cultivars released by IRRI grew out of elaborate collaborations among many national research institutions in Asia, permitting a *quantum* jump in the exchange of genetic material and the multi-locational, coordinated testing of new genetic material. These new kinds of IAs, based on networking among public research institutions, with the hub located at an international center, set a pattern for the future as new.

Similar international centers of agriculture research were subsequently established for other food staple crops and latterly also for forestry, water, and food research, and in support of national agricultural research (cfr. www.cgiar.org for list). The family of organizations was constituted under the Consultative Group for International Agricultural Research. The products of the CGIAR's unprecedented mobilization of scientific capacity for the sake of subsistence farmers in poor countries were important over the years, contributing to what became known as the Green Revolution, which was discussed in subchapter 2.1. Under the impulse of the Green Revolution many national institutes for agricultural research were created or reorganized in Asia and Africa, in recognition of the importance of technological change in the modernization of agriculture. The seeds of the new high-yielding varieties, and the packages of technology associated with them – such as inputs of fertilizers and pesticides and irrigation - catalyzed the national research centers to carry out adaptive and applied research in agriculture. The advances in knowledge that this research produced were openly published and freely shared. The technology developed by the Green Revolution science often was subsidized and incentives were provided to farmers (sometimes with coercion) to adopt the technologies on farm. In some cases, research and extension activities were carried out by the same institute, such as INTA in Argentina.

Biocontrol was also used as another tool by CGIAR. A well-known story is the fight against the cassava “mealy bug” in Africa, which caused major damage to the cassava plant, leading to serious yield losses (Neuenschwander, 1993). The IITA launched a major international collaborative effort, involving also CIAT to search for and find a natural predator of the mealy bug in Brazil in the “area of origin” of the cassava crop. Subsequently, dissemination of this natural enemy of the cassava pest in Africa required a major effort over several years by numerous African partner institutions, coordinated by IITA. It was reported that this inter-agency effort had saved million of tons of cassava per year.
The focus on individual crops was seen to have limitations. Mixed farming – the basis of many smallholder farming systems- was not addressed systemically. Despite the existence of two centers focusing on livestock, their impact on livestock production in developing countries was never comparable to centers devoted to crops. In addition, it became clearer over the years that the management of natural resources deserved as much attention as crop production. These concerns led to the creation in the 1970s and 1980s of another wave of international agricultural research institutions outside the ambit of the CGIAR (e.g. IMMI: water and irrigation, IBSRAM: soils, ICRAF: agroforestry, ICLARM: aquatic resources, and INIBAP: plantains and bananas). Generally speaking, these newer institutions have developed more extensive networks of partnerships with a wider range of civil society and public agencies than the original crop research centers supported by the CGIAR. In the early 1990s the centers were brought to expand under the CGIAR ambit after much discussion and resistance by some who feared that the expansion of the CGIAR would entail a reduction in funding for the initial centers.

Two major concerns drove this expansion: the perceived need to widen the research agenda to include a systematic focus on natural resource management, and a broad recognition of the need for CGIAR centers to diversify their partnerships and networking capacity. The international centers were thus driven by a growing pressure to address new issues, mainly related to natural resource management, and to address more directly than before the needs of the poorest producers and of under-valued clients such as women.

More generally, the CGIAR was placed under continuing pressure by a majority of its funders to adopt more efficient, inclusive, and cost-effective modes of governance. The establishment of an NGO committee (not currently operational) to strengthen and broaden interaction with civil society actors and organizations was one response, but the members encountered some difficulty in establishing a shared vision and sense of priorities. The tendency by some in the CG centers and in development assistance agencies, which provide the bulk of the funding, to assign farmers and other civil society actors a ‘downstream’ role, largely confined to local adaptation of already developed technologies and to extension activities, was challenged by the evidence that the civil society actors brought to the table, of their growing role in working with farmers. For example, in participatory plant breeding, varietal selection, integrated soil, nutrient and fertility management, catchment management, community forestry, rangeland restoration, water harvesting, and so on. On the other hand, the effort to broaden the expertise of the members of the formal governance structures tended to increase the overhead costs. The consensus view was that the international centers needed to substantially change their modes of operation and diversify their partnerships at the working level.

*Recent developments: Challenge Programs and GFAR.* In response to donor calls for more efficient, collaborative and also cost-effective approaches, the CG centers began to open up to new modes of collaboration, including ‘system-wide programs’ that draw together expertise from across the range of CG centers in order to focus on specific themes, and to draw in non-core funding to support ‘partnerships for innovation’. The increasing focus on innovation rather than fundamental, adaptive, and applied research and technology development, in turn required the CG centers to pay more attention to institutional issues and the contexts in which a technology is inserted. It also led them to seek a wider range of partners from among civil society actors and the private sector, in recognition that a new global agricultural research system was emerging (Petit et al., 1996). A multi-stakeholder group based in the World Bank nonetheless became increasingly concerned at the slow rate of change within the CGIAR, and the perceived resistance of some within the system to the need to adjust and their desire to maintain the quasi-monopoly position of the CGIAR centers on the international scene. The solution in part was held to be the introduction of competitive research grants. These eventually took the form in 2001 of well-resourced, multi-stakeholder, regionally focused “Challenge Programs” (CP) (CGIAR, 2001). Their emphasis on multiple partnerships is a potentially significant institutional development for the CGIAR system; as yet, there is insufficient evidence to assess this program’s contribution to the sustainable development goals.
Responding to the same concerns that the CGIARs faced, the Global Forum on Agricultural Research (GFAR) was established in 1996 as an initiative to promote cost-effective partnerships and strategic alliances amongst actors involved in agricultural research. Few studies however have assessed GFAR’s contribution to the sustainable development goals.

*The changing balance of public and private effort.* The picture that emerges from a comprehensive review of the impact of internationally funded agricultural research (Evenson and Gollin, 2003) further nuances the emerging consensus. On the one hand, the very success of the CG has given rise to the question of whether further public investment in international and national agricultural research is necessary, at least on the scale that funded the GR.  Yet at the same time, the sustainability of the output gains already made have been questioned, in the light of continuing changes in the volume and composition of population-driven demand, and in the light of the environmental consequences of industrialized production, such as soil degradation, loss of biodiversity, chemical pollution, aquifer depletion and soil salinity – effects that have been attributed to the intensification of production enabled by the technological pathway pursued by the CGIAR institutes. The differential socio-economic impacts of CG technologies also have led many commentators to question whether the current pattern and technological focus of public investment can meet the goals of equitable and sustainable development.

At the same time, it is recognized that the reduction in the size and resources of public agencies in many developing countries represents a rupture with earlier state-centered policies and agricultural service provision (Alston et al., 1998). At issue is whether the private sector can and will fill the institutional and knowledge gaps created by the decline in public research and extension in developing countries. Economic theory suggests that private research funds will go to where returns are possible and reasonable profits for the company can be generated, and that the rewards will be shared mainly with the farmers who already own significant productive resources. Nowadays private for-profit research concentrates on countries with large markets, a robust scientific system and favorable government policies (see 2.2.5). Some governments and donors have tried to further the public impact of private research in food and agriculture by easing restrictions to private participation and by ensuring that appropriate public interest regulations are installed and implemented. However, the present evidence is that, if governments stop funding research on public innovations with limited market potential but high public welfare, the private sector is unlikely to fill the gap completely, and that essential public checks on private knowledge claims will not be made. The reduced participation of the public sector in agricultural research and extension also has had negative implications especially for those farmers with limited resources, poor capacity for organization, and farming in areas highly sensitive to economic and environmental stress.

According to Byerlee and Alex (1998), the funding crisis in public interest research, and especially in the core funding base of the CGIAR, is paradoxical because it has arisen even though there is huge evidence of the high pay-offs to past investments in public good agricultural research. Such dis-investment is of particular concern for many developing countries, because there is a highly skewed concentration of knowledge production in food and agriculture in a handful of companies in developed countries protected by patents and intellectual property rights (CEPAL, 2002), and the evidence to date suggests that private sector agricultural and food research is not likely to generate large impacts on production or social welfare, or to address the needs of vulnerable populations who exercise low effective demand, or the constraints of the less favorable agro-ecological zones, or the environmental effects of intensification based on the availability of cheap petrochemicals and synthetic chemicals.

It is in this context that the CGIAR's Challenge Programs need to show that they can make an impact. The fact that elaborate governance mechanisms have been put in place for each CP reveals an awareness that much attention needs to be given to the careful management of delicate relationships among numerous and unequal partners. Such governance processes entail many transaction costs in terms of the coordinating secretariat and of meetings among partners; and one must wonder at what level the share of total expenditures taken by transaction costs become prohibitive. These concerns have been expressed within the CGIAR, although the CGIAR Science Council (SC) expresses continuing support to the idea of the new 'research paradigm': "The SC agrees with the proponents that within the new research paradigm described in the proposal - one which advocates working closely with farmers, local institutions and relevant partners at the field sites - specific priorities can not at this stage, prior to in-field diagnosis and stakeholder agreement on the priorities for change, be expected without compromising the bottom-up, participatory research process itself." Clearly, the

Challenge Programs may be the beginning of new institutional arrangements but the contours of the map for the future remain unknown.

***2.2.5 Private sector arrangements***

*Public-private arrangements.* Over the last twenty years, farmers, traders and social justice activists together have shown the feasibility of bringing products to market sourced from commodity production systems that pay fair prices and wages to producers, a movement pioneered by traders, processors and retailers. Organizations such as *Solidaridad* have extended the concept and practices, by linking fair trade to high return markets, such as the fashion industry, and more recently, by moving an increasing amount of fair trade product into mass marketing. This effort is being guided by the multi-stakeholder negotiation of Codes of Conduct. For instance, the Common Code for the Coffee Industry was introduced in September 2004. It is currently operating in Vietnam and Uganda, with plans for major expansion from 2006, under the sponsorship of the German Ministry for Development Cooperation, the German Coffee Association, producer associations and major coffee processors, such as Nestlé, Tchibo, Kraft and Sara Lee, and international organizations such as Consumers International.

In Argentina, the Seed Nursery at the Faculty of Agronomy of the Buenos Aires University together with the Argentine Agrarian Federation have developed high-yielding non-Bt corn hybrids, which are released to market at less than half price than those of the main competitors, are locally adapted and more affordable to smallholder farmers (at http://www.faa.com.ar/, Report Nº 167, 2005).

*Private sector arrangements for profit*. The last sixty years have witnessed a rapid increase in the concentration of commercial control by a handful of companies over the sale of planting seed for all the world's major traded crops – by 1999, seven companies already controlled a high percent of global seed sales and the concentration has since increased through take-overs and company mergers. Budgets of top 6 agrochemical companies in 2001-2002 combined equaled US$3.2 billion – compared to total CGIARs budget in 2003 of US$330 million, an order of magnitude less. (Dinham, 2005). The CGIAR's annual turnover is also less that that of leading European agricultural universities (e.g. Wageningen Agricultural Research, Euro 592 million, 2005).

At the same time, national small and medium-sized seed companies have emerged playing an important role for small farmers and niche markets. They will result in improved market access by smallholder farmers to locally adapted and affordable seed. In this respect, the Seeds of Development Program (SODP) is a capacity building and network initiative that seeks to alleviate rural poverty through improved access to appropriate seed varieties. It offers an innovative program for small and medium sized indigenous seed companies in Africa. The network currently includes 25 seed companies in eight African countries. The SODP is a project of Market Matters, Inc., a US-based organization working in collaboration with Cornell University.

### *2.2.6 Non-governmental organizations/other civil society networks*

Non-governmental organizations (NGOs) are the so-called ‘third sector’ of development, which is different from, but interacts with both the state (public) and the for-profit private sector in relationships ranging from complementarily to challenge (Farrington, 1993). The NGO sector developed in response to the actual and perceived failures or shortcomings of the state, the necessity to examine developmental questions from a motive not linked to profit (as is in the case of the private sector), but still in response to the conditions created by market forces, and to question and analyze organizational agendas and conditionalities imposed by donor agencies which result in the propagation of certain developmental and agricultural paradigms.

The way in which the NGO sector differs from the public and private sectors is that “the fundamental basis of NGO sector is voluntarism, eschewing the resort to authority and coercive means exercised by the state and forswearing (sometimes not entirely) the profit incentive of private enterprise” (Uphoff in Farrington, 1993). The NGO sector is not a uniform one, and it is useful to understand the wide range of NGO types in existence. The diverse NGO sector adopts a wide range of ‘modes of action’, gives credence to a variety of knowledge types and adopts varying typologies of knowledge processes in its operation.

A useful NGOs classification distinguishes them by *their origin* (Southern, Northern, Northern with activities in the South etc.); the *nature of their work*- grassroots organizations (such as communities, cooperatives, neighborhood communities, etc.), organizations that give support to the grassroots, and those that (whether in addition to other activities or solely focused on this) are engaged in networking and lobbying activities; their *funding*; *relationships with the state and private sector; their membership base; the size, staff range and relationships with their constituencies* (which could be as diverse as rural farmers, urban slum dwellers, indigenous tribes), and *their directions of accountability* (Farrington, 1993).

In the case of the agricultural sector this diversity of NGO types translates to NGOs working with farmers with close involvement in dissemination of farming techniques and processes, provision of agricultural inputs, technologies, access to markets and implements (i.e. developmental NGOs); NGOs that are engaged in conducting research on agricultural crops, processes and products (research NGOs); NGOs that lobby for specific issues related to agriculture ranging from farm-worker health, to gender empowerment among farming communities, to advocating for specific regional, national and international agriculture and trade policies (advocacy NGOs); NGOs focusing on activities such as micro credit necessary for farmers and agricultural communities (support NGOs).

The nature of activities that NGOs undertake, their relationship with the state and the private sector, their core constituency and nature of their involvement with it, their own organizational character and staff profile determine the attitude of an NGO towards the kinds of knowledge it considers valid- and consequently the nature of knowledge processes it engages with and utilizes in its interactions with its constituency. These phasal trends vary mainly by region, NGO type and context. For example, we see that in their inception, several NGOs began with a top-down process of information dissemination to farming communities, reflecting the nature of developmental work limited only to requiring farming communities as passive recipients of knowledge and information. The gaps in this approach prompted a shift towards other models of engagement with the validation of the local knowledge and knowledge processes of farming communities. These paradigmatic phase shifts in NGO-local farming community interactions and hence of the knowledge processes considered useful and acceptable by NGOs include: participation (of farming communities) in information giving (by NGOs), in consultation, and for material incentives, functional participation, interactive participation and self-mobilization of farming communities with NGOs as facilitators (Pretty, 1994). This rather simplistic characterization captures the basic phasal trends in shifts in NGO knowledge processes over time and the changing validation by NGOs.

Reflecting the different knowledge processes that NGOs engage with are the different ‘technologies of engagement’ or tools that NGOs have used over time to operationalize in practice their commitment to a knowledge process. The technologies of engagement range from top-down dissemination of knowledge through NGO community trainers; to engagement with farming communities through user groups and participatory committees; to direct involvement of farming communities in agenda setting and knowledge selection through tools like PRA (Participatory Rural Appraisal), Agroecosystems Analysis (AEA), Farmer Participatory Research, Participatory Analysis and Learning Methods etc (Röling and Wagemakers, 1998; Pretty, 1994); to farmer-led agenda setting and field experimentation as seen in cases of participatory farmer field school methodologies in which NGOs have been engaged (Braun et al., 2005; Van den Berg and Jiggins, 2006).

#### *2.2.7 Capacity development*

Despite the decades of development assistance delivered through complex systems of donors, multilateral agencies, international agricultural research systems, non-governmental organizations, etc. many world areas still remain in the grip of grinding and persistent poverty and chronic hunger. In view of this rather gloomy panorama, many key decision-makers have tried different approaches to consider the same old, aggravated problems from different perspectives. Within this process, the concept of Capacity Development (CD) plays a main role on the current agendas of development organizations.

As technologies and institutions are changing fast and budgets for overseas development are decreasing, strengthening the capabilities of individuals, groups, organizations at different scales (local, national, regional and international) is crucial. High investments are being made in the development of organizational and institutional capacities. Yet, the design and management of CD efforts leaves much to be desired.

*Capacity Building and Capacity Development*. The conventional form of technical and financial aid which considered assistance mainly as the transfer of physical and financial resources and modern technologies to poor areas, coupled with technical education and training has been subject of criticism since the 1960s (Berg, 1993; Morgan and Brown, 1993; UNDP 1993; World Bank, 1998d). Some agencies stated that a sustainable development could not be achieved if development was envisaged as a kind of "service" paid to non-industrialized countries in credit lines, expert advice, training programs, etc. These countries tended to stagnate and become dependent on aid, and development efforts failed because local capacities could neither manage the activities nor maintain the facilities. Local groups were not empowered to spearhead development activities after external agencies were pulled out (Horton, 2002).

In the past decade, two intimately related terms have emerged: Capacity Building (CB) and Capacity Development (CD). They represent a turnaround in a continuous search for better results which evolved from the concept of institutional building in the 1950s and the 1960s, institutional strengthening and development in the 1960s and the 1970s, to human resource development in the 1970s and the 1980s (Kühl et al., 2004). The term CB was first introduced by Edward V.K. Jaycox (World Bank Vice President for Africa) in the early 1990s. It was coined to describe a new thinking, a new mode of activities and a very different approach to development cooperation. This change of paradigm was supported by a study conducted by Elliot Berg (United Nations Development Program), in which he concluded that more capital investment was indeed needed for non-industrialized countries, but it was even more important to conduct CB programs leading to better trained personnel and stronger institutions (Berg, 1993). CD popularity has permeated international institutions in the past years. The Agenda 21 of the United Nations, for example, has stated that the success of "sustainable development" largely depends on a country's "capabilities" to promote the development of "personnel and institutional capacities" (United Nations 1992: 37). In Africa, Mozambique has a Ministry of Capacity Development. At present, the World Bank has a website on CD, www.worldbank.org/capacity/, which provides an overview of the literature, case studies, lessons learned, good practices, etc.  The site reports many successful cases in the South see Asia in which clear links can be established between capacity and growth. However the specific cultural attributes of the region seem to suggest that experience is hard to replicate. Among the many examples, Ethiopia case illustrates how a comprehensive, consensus-based approach is meant to provide the necessary framework for collective action and strengthen the capacity of the state over time. Burkina Faso's focus on selective "entry points" (for example, financial management) as strategy for getting greater performance is also examined.  Mozambique's experience in re-building its society, private sector, and basic state institutions is being reviewed for lessons that might apply in a near future.

CB and CD are generally interchangeable and elastic terms, but there are some differences between them. On the one hand, they have in common the idea that only creating or reinforcing national capacities in assistance programs will bring about results. They imply a call upon governments of non-industrialized countries for interdependence, self-support and a greater share of the responsibility for development.  At the same time, they are based on several assumptions, such as that countries´

ownership of their own development is conductive to better achievements and that people's mindsets and behaviors are critical to project performance. Both concepts have been praised in the 1990s with the idea that an increase in capacities in non-industrialized countries would contribute to the achievement of project aims (Kühl et al., 2004 ).

On the other hand, the main difference between them lies with the emphasis on where development originates. The term capacity is defined as the ability of individuals and organizations to perform functions effectively, efficiently and in a sustainable manner (UNDP, 1998: 5). It includes all those attributes, capabilities and resources of groups and organizations that enable them to undertake their mission. CB implies that some agency outside the community or organization supplies the energy to increase its capacity (exogenous process). It creates a new buildup of capabilities from scratch. The term building often implies that activities are carefully planned and executed and follow a clear and detailed plan or blueprint (Horton, 2002). In contrast, CD comprises a further development of already existing capacities and implies more endogenous processes, more experimentation and learning than engineering (Horton, 1999). CD strongly relies on the idea that development actions are collective actions. Hence, a country's capacity is measured mainly by its ability to carry out collective, coordinated actions. As a result, it is now widely recognized that training and skills enhancement of individual development actors are not enough to ensure successful achievements of development program goals. An enabling environment facilitating collective actions must also be provided. That environment is made of institutions in the sense that institutions are frameworks of rules, procedures, and arrangements that can provide either incentives for action or constraints that impede action. As Kühl (2004) points out, CD can be considered a much more "`politically correct tem" and a successor of CB.

*Capacity Development levels*. CD may take place at different levels: individual, group, organizational, national, regional and international. If an intervention takes place on one level only, without taking into account direct and indirect forces, such as governance, rules, enabling environments, etc. its effects will dissipate (Kühl et al., 2004). According to his study, sustainable development is not possible without a simultaneous human resource development, organizational strengthening and establishing supportive environmental conditions. Thus, a model that was developed on the micro-level, such as an Aids project in a region of South Africa, could be taken up and replicated on a higher level, and thus it could lead to changes in the strategies of organizations and in the general political conditions. Anyway, this replication does not necessarily mean that what worked well in one level would bring about good results in the other. Besides, one of the main issues of CD is precisely how to move to more people and more communities (horizontal scaling) or how to expand from grassroots to policymakers, donors, development institutions, etc. (vertical scaling). CD tools, techniques and strategies will vary according to both pathways.

*CB and CD challenges.* CD programs have to face different challenges in program implementation, mainly to define the role of the state, the donors, and the local communities in its processes. Besides, CD programs have to avoid the one-fit-all temptation to believe that successful lessons in one country can be applied elsewhere. Nor to take for granted that scaling up can be automatically achieved without paying careful attention to new settings.

Building enabling environments for CD programs depends mainly on the overall governance environment which may or not be conducive for the demand for change and sometimes depends on the passing of laws as well as the establishment of organizations (teams, committees, administrative departments and companies) to successfully implement CD programs. Coping with traditional values can play a positive role; but in some cases they can impede collective development actions, thereby negatively affecting implementation capacity.

Other challenges to CD strategies are for example, how to articulate private and public interests, international and national aims, etc.  Poverty and hunger will not be overcome by piece-meal tactics or marginal add-on projects. Besides, more evaluations are needed to have a record about CD programs, to test program basic assumptions and to determine if their aims and expectancies are fulfilled (Horton et al., 2001). Anyway, despite the fact that CD cannot be properly assessed due to the many explicit and implicit aspects intervening in development aid programs, decision makers may have to consider future scenarios related to AKST and CD issues counterfactually and ask themselves a series of questions -*inter alia*- : What kind of food and farming systems would be possible in the absence of farmers with basic literacy and numeric, organizational and leadership ability and occupational education? What are the implications for the stability and security of food systems in the absence of significant public capacity to check the truth claims of private enterprises, or develop alternatives unlinked to the search for private gain? Is an independent farming sector - delivering to competitive markets, but not contracted under private parties - a capacity necessary for secure food futures and pro-poor development, or a historical relict, best forgotten? If urban based factory food production is possible -as it technically now is, e.g. for meat muscle and many foodstuffs - if it can be called that - made from manufactured proteins, what kind of capacity will be needed?, would it imply process managers rather than farmers, for instance; food engineers rather than agronomists? Is animal health and zootic disease a growing concern? If so, then veterinarians may move up the hierarchy, of CD needs with a related need for closer collaboration with epidemiologists and human health specialists and public health regulators? Is management of what is called 'manufactured risk', e.g. risks that emerge from human choices, rather than as forces of nature, a growing CD domain?

## 2.3. AKST Evolutions over Time: Thematic Narratives

The different arrangements studied in sub-chapter 2.2, their implementation, and evolution, have been causes as well as consequences of the main changes in AKST. Although it appears currently that AKST presents itself as a whole, or at least as a tightly intertwined ensemble of domains, it has not always been the case. Progressively, over centuries, a hierarchy developed itself between scientific knowledge, technological knowledge and agricultural production, the latter being progressively limited to an execution of external recipes. Paralleling this hierarchy, science itself established a hierarchy between emerging and evolving disciplines: chemistry, biology, genetics, botany, entomology, economy, sociology, and anthropology are permanently struggling for recognition, status and resource, and scientists engage in alliances with other actors in this purpose. Hence, science allied with technology branched out in different domains of application that resulted in new professions related to various aspects of agricultural production, its products and impacts. Eventually, the resulting characteristic of our modern times is then that the role of scientific research in maximizing agricultural productivity has increased exponentially (Cernea and Kassam, 2006).

However, through the last decades, a reverse movement has occurred and the division between the different branches of AKST have been blurred, the great divide of labor between science and technology is currently challenged, the hierarchy among disciplines reveals its shortcomings and the role of public and private actors has changed.

Subchapter 3 presents three examples of this evolution in order to highlight more precisely the main drivers at work behind these dynamics and draw lessons to face the questions of the future. These examples are presented as thematic narratives, telling the stories of how AKST contributed and shaped (as well as it resulted from) the management of three major elements indivisibly linked with agriculture in the production process, seeds and pests, or as its main output, food.. These narratives are meant to identify trends, turns, and bifurcations in each domain and to look at the major actors who managed them, in response to drivers relevant for them. The interest in following these three threads is to feed a comparative analysis and finally to produce a transversal approach of AKST which fits with the contemporary situation of the world agriculture.

### *2.3.1. Historical trends in germplasm management and their implications for the future*

2.3.1.1. Summary of major trends in the history of global germplasm management:

Genetic resource management in the past 150 years has followed a trend of conceptual reduction and institutional narrowing. Breeding is now seen as an isolated activity, separate from agricultural and cultural systems (see box 2.3).

INSERT BOX 2.3 HERE

Farmers have received no direct compensation for formerly held public accessions, but have generally benefited from public breeding arrangements. It remains a question if farmers now have to pay for accessing seeds and germplasm that contain lines and traits that originally were bred by them and originated in their own farming systems.

There has been a strong movement toward unprecedented concentration among agro-chemical companies, seed companies, and food commodity trading companies. This movement is correlated to an increasing trend toward germplasm passing from public to private ownership. Decreases in funding for public breeding has stagnated research innovations for the public good (e.g. lack of research on orphan crops). New ownership and IPR regimes have restricted movement and made development of non-commercial (public) good constructs more expensive. These changes have limited those actors that do not have legal, commercial and financial power.

2.3.1.2. Genetic resources as a “common heritage”

*2.3.1.2.1. Farmers as managers of genetic resources*

Historically, farmers have been the principal generators and stewards of crop genetic resources (e.g. Simmonds, 1979). This means that genetic resources have been viewed as a “common heritage” to be shared and exchanged. The concept places farmers at the center of control of their own food security. The planting of genetically diverse, geographically localized landraces by farmers can be conceptualized as a decentralized management regime with significant biological (Brush, 1991;Tripp, 1997; Almekinders and Louwaars, 1999)and political (e.g. Ellen et al. 2000) implications (see box 1). . Studies of traditional farming systems suggest that farmers in Africa (Mulatu and Zelleke 2002; van Leur and Gebre, 2003) the Americas (Quiros et al., 1992; Bellon et al., 1997, 2003; Perales et al., 2003) and Asia (Trinh et al., 2003; Jaradat et al., 2004;) managed and continue to manage existing varieties and innovate new ones through a variety of techniques including hybridization with wild species, regulation of cross-pollination, and directional selection (Bellon et al. 1997). In many parts of the world, it is women’s knowledge systems that select and shape crop genetic resources (Tsegaye, 1997; Mkumbira et al., 2003; Howard, 2003). The fear is that erosion of crop diversity is commonly paralleled by erosion of the farmer’s skills and farmer empowerment. This loss of farmer’s skills means a loss of community sovereignty as less of the population is able to cultivate and control their own food (see 2.3.3).

*2.3.1.2.2. Development of public and private sector*

The public sector emerged to catalyze formal crop improvement, focusing on yield with high input requirements and wide adaptability (Tripp 1997; Almekinders & Louwaars 1999). This had both negative and positive impacts for farming communities as more uniform crops replaced locally adapted crops. Meanwhile, expeditions to collect global germplasm were underway by several nations and gene banks were established for the conservation of germplasm and use in research and breeding.

INSERT BOX 2.4 HERE

Public sector institutions were the dominant distributors of improved varieties in first half of the 20th century, aiming to reach as large a constituency possible. Where different forms of mass selection formed the main breeding method in the 19th century, the rediscovery of Mendels laws of heredity (1900) and the discovery of heterosis (1908) spurred the growth of the commercial industry, most notably with the founding of Pioneer Hi-Bred in 1919 (Crow, 1998; Reeves and Cassaday, 2002). Throughout the 20th century, universities and research institutes gradually specialized in basic research while the private sector increased its capacity in practical breeding. The public sector assumed primary responsibility for pre-breeding, managing genetic resources and creating scientific networks that acted as conduits of information and technology flow (Pingali and Traxler, 2002), and creating regulatory bodies for variety testing and official release, and seed certification.

*2.3.1.2.3. The first institutional arrangements exported to developing countries.*

The education, research and extension system triangle was exported to developing countries to help foster agricultural development and food security, mainly through the development of broadly adapted germplasm. With the aid of the Rockefeller Foundation (and later the Ford Foundation), a collaborative research program on maize, wheat and beans in Mexico was founded in 1943 that laid the foundation for the first international research centers of the Consultative Group on International Agricultural Research (CGIAR), which initial focus was to improve globally important staple crops. It built on existing plant-breeding capacities in colonial institutions such as botanical gardens and commodity research centers (Reeves and Cassaday, 2002). Currently there are 16 such centers that operate under the CGIAR. Drivers for development of the research centers were economies of scale and public-good nature of the output (Evenson and Gollin 2003).

INSERT BOX 2.5 HERE

The formation of the CGIAR centers laid the groundwork for the emergence of the technologies of the Green Revolution. Borrowing from breeding work in developed countries, high yielding varieties (HYV) of rice, wheat, and maize were developed in 1960s and 70s. By 2000, 8000 modern varieties had been released by more than 400 public breeding programs in over 100 countries. The FAO launched a significant program to establish formal seed production capacities and so-called ‘lateral spread’ systems in developing countries to make the new varieties available to as many farmers as possible. These public seed projects, financed by UNDP, World Bank and bilateral donors were subsequently commercialized, often as parastatal companies, before national or multinational seed companies established in these developing countries (Morris 1998, 2001, WB 1995). Private seed production is commonly only possible for high value crops (e.g. vegetables, oil crops) and crops for which hybrid technology is available such as maize and pearl millet.

Few HYVs however, were developed for sorghum, millet, barley, pulses and root crops until the late 1980s and for maize and rice, few suitable varieties were available for the Middle East an Africa (Evenson and Gollin 2003a; Johnson & Manyong 2003 ). The FAO has estimated the economic and social consequences of crop genetic improvement gains emanating from the international agricultural research centers using the IFPRI based model ‘IMPACT’ (Evenson and Gollin 2003b). Without CGIAR input, it is estimated that world food and feed grain prices would have been 18-20% higher: world food production 4-5% lower, and imports of food in developing countries about 5% higher. However, food consumption per capita is estimated to have declined for many groups (Evenson and Gollin, ibid.) and debates continue as to whether increases in food production, such as those of the Green Revolution, necessarily lead to increases in food security (IFPRI, 2002 see box 3 & Food narrative).

INSERT BOX 2.6 HERE

*2.3.1.2.4. Sharing of genetic resources as historical norm*

Until the 1970's, there were very few national and international laws creating proprietary rights, or other forms of explicit restriction to access to plant genetic resources. The "common heritage" concept of genetic resources as belonging to the public domain had been the foundation of farming communities for millennia where seed was exchanged and invention was collective (Brush, 2003). Farmers and professional breeding have relied on genetic resources, in the public domain or in the market, to be freely available for use in research and breeding. The public-sector research 'culture' is based on this tradition of open-sharing of resources and research findings (Gepts, 2004), although this is changing (see below) and has serious social and political implications. Indeed, the global collaboration required for the development of the HYVs of the green revolution demonstrated the effectiveness of an international approach to sharing of germplasm. The International Undertaking on Plant Genetic Resources, 1983, encapsulated this spirit citing the "universally accepted principle that plant genetic resources are a heritage of mankind and consequently should be available without restriction." Since that time, in many ways, the common heritage principle has been turned on its head, with the gradual encroachment of claims for control over access to and use of genetic resources grounded in intellectual property laws, assertions of national sovereignty (Safrin, 2004) and or the intentional use of technologies that cannot be re-used by farmers.

That said, the common heritage or public goods approach to the use of Plant Genetic Resources for Food and Agriculture (PGRFA) has not been entirely eclipsed. It is worth noting in this regard that the Union for the Protection of Plant Varieties (UPOV) Conventions through their several revisions to further strengthen of breeders' rights have consistently maintained a "breeders' exemption" which allows researchers/breeders to use protected materials in the development of new varieties without the permission of the owners (as long as the new varieties are not 'essentially derived' from the protected varieties). Furthermore, in what might be considered a surprise development in the context of the overall shift in the GR paradigm, the International Treaty on PGRFA creates an international research commons within which  individuals and organizations in member states, and international organizations that sign special agreements, enjoy facilitated access (and benefit sharing) on preset, low-as-possible transaction costs. More is written about access and benefit sharing, and the International Treaty in particular below.

2.3.1.3. Major change in germplasm management

*2.3.1.3.1. The development of Intellectual Property Rights (IPR) in breeding.*

*The stakes.* The business environment and size of the market are determining factors for investment and seed laws, and biosafety laws may provide some level of protection. With the introduction of IPR, the private seed industry benefits from the ability to appropriate profits to recoup investments and foster further research, organizational capability and growth (Heisey et al. 2001). The stakes are high; IPR regimes have transformed the $21 billion dollar global seed market and contribute to the restructuring of the seed industry (ETC 2005).

The increasingly international character of IPR regimes is a reflection of widespread and integrated trade in germplasm resources as well as global trends toward liberalization of markets and trade, privatization, and structural adjustment that reduce the role of the public sector (Tripp and Byerlee 2000).

*An evolution towards a corporate privilege.* Germplasm protections have been both biological; (e.g. hybrid maize) and legal. Initially plants were excluded from patentability for moral, technical and political reasons. for example, special, so-called *sui generis* protection was developed for asexually reproduced plants (US Plant Act 1930) and in Europe for all varieties in the 1940s, harmonized through the Union for the Protection of Plant Varieties (UPOV 1961). This Plant Variety Protection (PVP) system recognized farmers and breeders exemptions. However, this was soon to change; a Utility Patents (UP) on a bacterium in 1980 signalled the advent of an era of strong Intellectual Property Rights (IPR) (Falcon and Fowler 2002).

It is argued that IPR is essential for private seed sector development. While PVP offers protection to private seed producers by prohibiting others from producing and selling the protected variety commercially, it does not restrict anyone from using a protected variety as parental material in future breeding. This is known as the ‘farmers’ privilege’ and responds to the traditional seed handling mechanisms and allows farmers to save and exchange seed (1978 Act), a provision which was interpreted very widely in the USA, leading to large scale ‘brown bagging’.

To the detriment of farmers, this privilege was restricted in the latest revision in UPOV (1991 Act). Patents, which entered the plant breeding initially through court decisions in the USA in the 1980s in association with biotechnology, and subsequently granted in other OECD countries, offer a greater protection of a wider array of products and processes, such as genes, traits, molecular constructs, and enabling technologies (Lesser and Mutschler, 2002). However, varieties are excluded from patentability in most countries, the EU introduced a breeder’s exemption into its patent law, and in addition to that some EU countries introduced a farmers’ privilege as well to avoid too strong protection (World Bank, 2006)

*2.3.1.3.2. IPR limitations.*

Even though IPR may be important for private seed sector development, such sectors have been rather successful in developing countries without IP protection. For example, the private seed sector in India has grown and diversified without the benefit of IPRs but in the context of liberal seed laws and in many cases through the use of hybrids as a means of appropriation (Louwaars et al, 2005).

Some indicators suggest that the IPR in developing countries may have occurred primarily as costs. Too many patents may, however, also slow down research. This problem is described as “the problem of the anti-commons" (Heller and Eisenberg 1999) or "patent thickets" (Shapiro 2001, Pray et al., 2005). Consider the example of Veery wheat, which is the product of 3170 different crosses involving 51 parents from 26 countries that was globally, publicly released. The impact on the development cycle of Veery would have been very significant if, for each parent and each cross, it was necessary to negotiate a separate agreement (SGRP 2006).

IPR are territorial, i.e. granted at the national level. Trade arguments however, lead to greater 'harmonization' of IPR regimes (Falcon and Fowler 2002), initially through the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS, 1994) of the World Trade Organization (WTO). This forces some countries to adopt laws and rules that may not be of benefit to seed-saving farmers. In addition, many developing countries are now required to establish more stringent IPR agreements as a result of bilateral or regional trade agreements which seek to impose IPR regimes that are stronger than the minimum requirements of TRIPS agreement, creating challenges to complying with the Convention on Bio Diversity (CBD) (Louwaars et al. 2005). However, TRIPS has not been particularly effective at stimulating research on crops in general, and particularly for the kind of crops grown by poor farmers (CIPR 2001).

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In many developing countries institutional infrastructure required for implementation and enforcement of IPR regimes is still missing and wherever it has come up it currently plays a marginal role only. Opposition against TRIPS and the IP-clauses of free trade agreements concentrates on the lack of incentives for development of the seed industry in developing countries due to the harmonization approach. However, in agricultural biotechnology development, which is highly concentrated, the IPR issues precipitate more in the form of licensing practices and policies, shaping the impact of patent systems to a large extent. Consequently, there has been a misconception that existing problems can be best solved through reshaping patent regulations and laws alone. There is a related need to examine how licensing agreements contribute to many problems at the intersection of IP and agricultural biotechnology (CIPP, 2004).

*2.3.1.3.3. Sharing of genetic resources; challenge and necessity*

*A reaction to IPR: national sovereignty and equity issues*

The lack of explicit rules governing germplasm rights was the historical standard in agriculture until the 1990's. As pressure to protect intellectual property rights in improved varieties and 'inventions' increased, the atmosphere concerning access to and use of genetic resources became increasingly politicized. This was augmented with concern, particularly among developing countries, that inequitable global patterns were established in the distribution of benefits associated with the use of genetic resources. Concurrently, there was growing concern that genetic diversity and local knowledge related to the use of those resources continued to be eroded under the pressures of modernization (Gepts, 2004).

In response, the international community entered into a process to attempt to address these tensions and create a new regime for access to genetic resources and the sharing of benefits associated with their use. One of the most significant outcomes was the Convention on Biological Diversity (CBD, 1994, see box), which came into force in 1993. The CBD emphasized states' sovereign rights over their natural resources and their "authority to determine access to genetic resources, subject to national legislation." The CBD also establishes that states shall endeavor to create conditions for facilitate access to genetic resources, and that such access, when granted, should be subject to prior informed consent, and subject to mutually agreed terms. The Convention also addresses rights of local and indigenous communities in this respect and its Cartagena Protocol of the CBD seeks to control potentially hazardous material (mainly transgenic) across borders. Most countries have interpreted the access and benefit sharing provisions of the CBD as the basis for establishing much tighter procedural and substantive restrictions to gaining access to genetic resources within their borders. To this end, they have developed, or are developing, bilaterally oriented access laws that require case-by-case negotiations to establish legal conditions for obtaining and using materials from a country although they are not binding, and few countries have reported implementing them; nonetheless, they are a good indicator that most countries think of the CBD's access and benefit sharing provisions as requiring, or justifying, a bilateral and restrictive approach to regulating access.  Very different approaches were taken by countries to implement their sovereignty rights. Noticeably, the African Union and some individual countries in Asia (notably India and Thailand) developed an approach that combine aspects of access and benefit sharing and breeder's rights in one regulatory framework clearly indicating the connection between the two issues.

While a restrictive bilateral approach to implementing the CBD may be appropriate for wild endemic species of flora or fauna, it is not well suited to plant genetic resources for food and agriculture. All domesticated crops are the end products of human intervention (mostly farmers) and would disappear in the absence of continued intervention. Most are the end result of contributions of farmers from numerous countries or continents over extremely long periods of time. Evidence of this internationalism can be found in studies of crop variety pedigrees and international exchanges of PGRFA in support of breeding. Countries are interdependent upon PGRFA for food security. By establishing a multilateral system on access and benefit sharing, the International Treaty on Plant Genetic Resources for Food and Agriculture reflects the world community's appreciation of these facts about PGRFA. However, the legally binding CBD explicitly closed the concept of 'heritage of mankind' that had been expressed in the 80's by the non-binding International Undertaking. CIP and IRRI, have reported that since the CBD came into force movement of plant varieties from and to their gene bank collections have been noticeably reduced and regulation of biological materials has resulted in increased bureaucracy and expense.

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Visser (et al., 2005) furthermore identify that there are hardly any cases of effective (even nonmonetary) benefit sharing as a result of CBD-based regulation during the first decade of the Convention. Thus, promoting fair and equitable sharing of the benefits arising out of the use of genetic resources remains a major goal. Defining a monetary value to estimate the historic or current contribution of farmers' varieties remains elusive (Mendelsohn, 2000). Identifying the actual genetic resource property attributable to specific farming communities or even nations is "problematic" (Peeters and Williams, 1984; Visser et al. 2000). Some proponents have argued that benefit sharing would be more successful in the form of transfer of international capital, e.g. through development assistance to improve rural incomes in genetically diverse farming systems (Brush, 2005). Another approach could be to reduce structural adjustment policies that link agricultural credit to the planting of modern homogeneous varieties, and other crop and technology choices (Morales, 1991; Foko, 1999; Amalu, 2002).

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Safrin (2004) identifies a connection between the genetic resources policies and the strengthening of intellectual property rights, leading to "hyperownership in a time of biotechnological promise". Louwaars (2006) adds that "Groups that oppose the legal enclosure of genetic materials through IPRs have, paradoxically, promoted the development of mechanisms that keep even more materials out of the public domain."

*The question of facilitated access.*_To match the principle of national sovereignty with the needs of sustainable agriculture and food security, an International Treaty for Plant Genetic Resources for Food and Agriculture has been concluded in 2001. With roughly the same objectives as the CBD it translates its conservation and sustainable use goals to agriculture, including both *in situ*, on farm and *ex situ* conservation strategies, and various aspects of crop improvement by both farmers and specialized plant breeders in implementing 'sustainable use'. The main novelties in the International Treaty are the creation of a Multilateral System for Access and Benefit Sharing for most important food crops and pasture species and the definition of the concept of Farmers' Rights. The Multilateral system is to be implemented through a standard material transfer agreement making individual negotiations unnecessary. A funding mechanism in which the FAO is likely to play a leading role is designed to collect and distribute benefits to farmers (Visser & Louwaars, 2006). Farmers' Rights include the right of benefit sharing, of protection of traditional knowledge and of farmers' involvement in relevant policy making. The rights furthermore should not limited the ability of farmers to save, use, exchange and sell seed. However, signatory countries have a lot of freedom in specifying the Farmers' Rights at the national level and more specifically, the rights to save, use, exchange and sell seed has to be granted "subject to national law and as appropriate". The latter formulation was chosen to avoid conflict with existing and future IPR laws and some commentators claim that this formulation has thus far prevented an international acceptance of an inclusive Farmers' Rights concept (Brush, 2005).

2.3.1.4. Increasing consolidation of the private sector.

*2.3.1.4.1. The changing face of the seed industry.*

Meanwhile in the context of newly emerging IPR regimes, the development of biotechnology (e.g. identification, cloning and transferring of individual genes) significantly altered the course of germplasm management. These mutually impacting developments mark a major shift in the relationship between the public and private sector, and were a major factor contributing to the consolidation of the agricultural plant biotechnology and seed industries (Pingali and Traxler, 2002; Pray et al., 2005).

The first wave of mergers featured the takeover of family-owned seed companies by multinational firms with an increasing move to link seeds and inputs chemicals (Thayer, 2001; Falcon and Fowler, 2002). Consolidation in the seed industry had been ongoing since the 1970s, but the unprecedented concentration in the 1990s resulted in the vertical integration of the seed and biotechnology industries (Hayenga, 1998) followed by a horizontal integration of agriculture and pharmaceuticals into life sciences companies. The first trend was largely driven by the stagnation of the agrochemical sector and the changing knowledge base and innovations in chemistry and biotechnology, and the policy environment such as the increased burden of regulations (Tait et al 2000). Between 1995 and 1998, in the US alone, approximately 68 seed companies either were acquired by or entered into joint ventures with the top 6 multinational corporations (King, 2001) seeking to establish a multinational structure allowing agribusiness companies to provide the upstream research, with the local seed companies providing the crop varieties developed for specific geographical markets (Fulton and Giannakas, 2001). The area with the greatest concentration intensity in the past decades has been genetic transformation (Pray et al. 2005 –see box). Meanwhile, in the developing world, structural adjustments, which reduced the role of the state, alongside increasing liberalization of markets and trade, accelerated the trend to privatization (Tripp, 2000).

Today, the top 10 agribusiness companies represent half of the world's commercial seed sales (ETC, 2005). Pray et al. (2005) show that the top ten biotechnology firms increased their control of biotech patents to over 50% in 2000. They suggest this could be a response to the anti-commons/thicket problem and that instead of negotiating for the rights to a competitor's technology, it might be simpler, cheaper, or more advantageous to acquire the competitor outright. Currently, patents on the foundational transformation technologies for grains are held by only three firms: DuPont, Monsanto, and Syngenta (Brennan et al., 2005).

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*2.3.1.4.2 Implications of concentration.*

A relatively stable market share may encourage corporations to invest in R&D, both in terms of current profitability and a reasonable expectation of future profitability. However, recent analysis suggests that we are seeing the beginning of trend towards negative impacts on innovation and competition through increased concentration within the private sector (Brennan et al., 2005). The major concerns are: (i) the concentration of the industry reduces the amount and the productivity of research because R&D expenditures are consolidated and narrowly focused; (ii) concentrated markets create barriers to new firms and quell creative startups; (iii) concentration allows large firms to gain a substantial monopolistic power over the food industry, making food supply chains vulnerable to market maneuvers (see food narrative) (Pray et al. 2005). For instance, a recent USDA study suggests that consolidation in the private seed industry over the past decade dampened the intensity of private research undertaken on corn, cotton, and soybeans crop biotechnology (Fernandez-Cornejo and Schimmelpfennig, 2004). This raises concerns that decreasing levels of research activity would stunt agricultural innovations, and brought into question whether large biotech firms can be relied on to conduct research with an eye on the public good as well as their own profit margins (Pray et al., 2005).

*2.3.1.4.3. The dilemma of the public sector*

The establishment and strengthening of IPR in agriculture has contributed to an increase in private investment in agricultural research (Moschini and Lapan, 1997) and a shift in emphasis from public to private breeding (Gray et al. 1999). Many public breeding programs have been unsure of whether to complement or compete with the private sector and confusion has arisen as to how to take advantage of IPR to control the use of their material (Reeves and Cassady, 2002) or to capture royalties for bigger budgets (Fischer and Byerlee, 2002). These trends have triggered concerns that that the lure of potential royalty revenue will distort research priorities in public institutions away from poverty alleviation and sustainability, as has been suggested by research managers in Uganda (Louwaars et al. 2005). However, IPR strategies may help in the establishment of public-private partnerships and in some cases, licensing of IP rights by private to public sector actors for humanitarian uses has facilitated technology transfer (e.g. rice rich in pro-vitamin A and Ringspot Virus Resistance for papaya to South East Asia (Brewster et al 2005, Al-Babili and Beyer 2005).

2.3.1.5. Farmers, public and private sector; roles and relations

*2.3.1.5.1. Changes in funding and investments.*

*The strengthening of the private sector vis à vis the public sector.* While global agricultural research investment has grown dramatically since the 1960's (more than doubling between 1976 and 1995), recent trends indicate a shift from public to private sector dominated research. In the 1990s, public sector research investment began to stall in developed countries, growing by just 0.2 percent annually between 1991 and 1996 (Pardey and Beintema, 2001). Globally, the private sector has accounted for approximately 35% of agricultural research, a figure that is projected to grow as privatization trends continue (Spielman and von Grebmer, 2004). The top ten multinational bioscience companies spend $3 billion annually on agricultural research, while the global CGIAR system spends just over $400 million. The three largest NARS in the developing world, Brazil, India, and China have budgets larger than the CGIAR (Byerlee and Fischer, 2001 but this is, however in marked contrast to other regions (Africa) where public sector research funding growth has declined. Meanwhile, funding the CGIAR - supported research centers has shifted away from research in staple crop improvement towards more generic natural resource management issues (including forests, water and fish), and become increasingly restricted (World Bank, 2003). The system has seen its funding decline over the last 15 years compared to the widening of its mandate to natural resource management issues (Pardey and Beintema 2001). Lack of funding for the CGIAR is expected to have negative effects on NARS plant breeding, particularly in Africa as more than one third of the approximately 8,000 NARS released crop varieties were based on IARC germplasm.

Structural adjustment programs have severely affected the ability of developing countries to support public R&D budget (Kumar and Sidharthan, 1997; CIPR, 2002; Chaturvedi, 2006). Moreover, USAid earmarked for agricultural research fell by 75% from 1980 to 1996. Given the importance of public sector agricultural research in developing countries (94% of total expenditures), a continued decline in public sector breeding, coupled with increased private sector growth will only increase the growing gap in research intensity between rich and poor countries. Despite the major agriculture growth of China, Brazil and India, developed countries had a research intensity 8 times higher than developing countries by the year 2000.

*Shifting roles of the public and private sectors according to profitability.* Historically, public sector institutions have been the dominant distributor of germplasm resources. Hence, both the national and multinational private sectors depended very heavily on public sector gene banks and pre-breeding in the development of their varieties (Morris and Ekasingh 2001). Private research has been and continues to be leveraged with public goods; projections indicate that investment in public research has a simulative effect on private investment (Fernandez-Cornejo and Schimmelpfennig, 2004). The growing private sector has focused on widely commercialized, competitive crops that are well protected by legal or technical IPR (Fernandez-Cornejo and Schimmelpfennig, 2004). This has meant that tropical crops and crops for marginal areas (and other public goods attributes, such as safety, health, and environmental protection), so called “orphan crops”, have remained outside the orbit of private investment (Naylor et al. 2004; Fernandez-Cornejo and Schimmelpfennig 2004). Improvements on major open-pollinated crops like wheat and legumes (Pingali and Traxler 2002; Guner and Wehner 2003) are still primarily in the public sector, since the ability to save seed reduces incentive for private investment (Frey, 1996).

There has also been a division of labor in agricultural research and development. Figures from the US in the mid-1990’s show that only 10% of private sector scientists were working on basic plant breeding (Frey 1996), while public institutions spent 46% of their expenditures on basic research (Klotz-Ingram and Day-Rubenstein 1999). In addition, public sector research may concentrate on public goods such as lower costs, increased productivity or other benefits that in specific cases are either not practical or desirable to protect with IPR, and therefore unlikely to attract private investment (Fernandez-Cornejo 2004).

*2.3.1.5.2. Emergence of new institutional arrangements.*

*Public-private partnerships to reach the Millennium Goals*. The changing character of the seed industry has highlighted public/private partnerships as potential generators of valuable synergies. There is the perception that while there has been greater participation by the private sector in the seed industries of developing countries, many of the larger corporations increasingly do not share information, technology and germplasm (IFPRI 2005). This trend raises questions on the future of the IARCs and international public breeding initiatives. Examples of public/private partnerships that are responsive to the needs of smallholder farmers have been reported through an IFPRI International Dialogue on Pro-Poor Public-Private Partnerships for Food and Agriculture (2005). Such partnerships include hybrid rice development in India, insect resistant maize in Kenya, industry led associations to improve seed policy in Kenya and collaborative effort to promote bio safety regulation in India (IFPRI 2005). Some of these have a strong charitable character; others include a clear, but often long term, commercial benefit to the private partner. Such partnerships can be successful as in the case of the Daimler Chrysler collaboration with Poverty and the Environment in Amazonia (POEMA) whereby coconut fibers and natural latex rubber are use by Daimler Chrysler (Laird 2002, Zahn 2001). A recent initiative, the Science and Knowledge Exchange Program, to exchange staff between the public and private sectors may go far to develop productive pro-poor partnerships in food and agriculture.

In Africa, schemes have been put forward to promote the acquisition of private sector innovations by the public sector at a price based on their estimated value to society (Kremer, 2003; Master, 2003). Private companies would contribute to crop improvement through partnerships that use local varieties and provide source and know-how for improved regulatory passage, for example in biotechnology and development (Cohen 2005; Keese et al. 2002). However for complicated genetic transformations (e.g. vitamin A-enhanced rice), dozens of patents are involved in a single transformation (Guerinot, 2000). In this case, all public and private IPR-holders must grant licenses to all intellectual property resting on the final product to allow freedom to operate in developing countries (Al-Babili and Beyer, 2005). To further facilitate use of privately held IP, a proposed solution has been a division of labor; if the public sector completes the preliminary adaptive GE research on orphan crops, such as teff, cowpea and millet which do not have a profitable seed market yet are locally important for food insecure areas in developing countries, this would lower the cost barriers to the private sector (Pingali and Traxler, 2002). Experience suggests that the public sector must take the lead in such initiatives on crops that are essential for food security, but have marginal profitability

INSERT Table 2.6 HERE

To date few success stories of public-private partnership have emerged, and even fewer examples have surfaced where partnerships have contributed to food security, poverty reduction and economic growth (Spielman and von Grember 2004).

*Renewed involvement of farmers in genetic resource management.* On-farm management of genetic resource is not only a historic phenomenon (see above), but also an active conservation strategy involving goal-based local and global initiatives. Today, farmers remain indispensable actors in any regime that seeks to conserve, improve, and disseminate genetic diversity. It is estimated that 1.4 billion farmers save seed from year to year. (Pimentel et al. 1992; Cleveland et al., 1994; Bellon 1996). However, on-farm maintenance of genetic diversity is threatened by social, economic and technological systems that are transforming traditional farming and supplanting diverse landraces with uniform varieties. Farmer based conservation strategies have been criticized as arresting modern agricultural development, and the increased production and income that sometimes accompany it (Brush, 2000). Today, this view has largely shifted as the advantages of *in situ* conservation gains recognition, in particular the relationship between diversity and yield stability (Amanor et al. 1993; Trinh et al., 2003; Abidin et al., 2005). The focus has shifted from on-farm conservation to on-farm management of genetic resources, creating room for the improvement of local varieties to cope with changing needs.

*Participatory Plant Breeding as a new arrangement.* Participatory plant breeding and *in situ* management relies on the collaboration between farmer-breeders and corporate plant breeders (Lipton and Longhurst, 1989; Sthapit et al., 1996; Kerr and Kolavalli, 1999; Almekinders and Elings, 2001; Witcombe et al., 2005). Traditionally, these projects are judged on their ability to produce adapted crop material at lower costs than conventional programs and on their ability to produce higher genetic gains per year (e.g., Witcombe et al., 2001; Smith et al., 2001; Virk et al., 2003, 2005; Ceccarelli et al. 2001, 2003). However, participatory research projects (comprised of both formal and informal actors) have also lead to the spread of socially responsible, technical innovations and important policy changes (Joshi et al. 2007). These innovations have been shown to improve the welfare of the poor and socially excluded. One of the best examples is a 1997 client-oriented participatory crop improvement (PCI) project in Nepal in which there was a formal recognition that informal R&D processes were taking place, and a move to encourage those processes (Biggs, 2006). This lead to changes in National Varietal Release Procedures and more effective collaboration between different actors. Informal developments were essentially legitimized and supported. Nevertheless, the benefits of farmer participation may not be universal, and adoption of participatory methods has not been as high as expected, notably because of methodological limitations to upscaling (Witcombe et al. 2005).

*The quality issue.* In developed countries, changes in the consumers' preferences and behavior put pressure on the regulatory framework that has been build after the World War 2. Several trends addressed the question of "genetic progress" and highlight the fact that products have also a non-material value. The labeling of the geographical origin of the products, along with the notion of "terroir", is often based on codes that explicitly exclude new varieties issued from research stations (Dupré, 2006). The local origin of the genetic resources is opposed to the standardization that resulted from the dominant institutional arrangements and regulations.

The development of organic and sustainable food production systems creates additional challenges to the regulatory arrangements. Organic farming requires seeds that are efficient in environments that are weakly artificialized. Then, instead of working on large recommendation domains of breeding for conventional agriculture, breeders have to select for specific adaptability to specific environments and practices. The E.U. regulatory framework (2092/91) has established that organic production must use seeds that have been produced in organic conditions. In this sector, farmers and specialized breeders are reviving old crop varieties (Bérard and Marchenay, 1995, Bonneuil and Demeulenaere, 2007) that have been abandoned and that may not be registered (any more) in the official regulatory framework.

Another trend of building new arrangements about seed management is initiated by the food chain parties that develop specific niche-markets for local products, in some cases based on local varieties with specific certification systems and contractual arrangements.

All these trends challenge the classical ways of evaluating varieties. The multi-factor and multi-site experimentation, backed by statistical analysis is more and more difficult to carry out and it calls for new ways of assessing varieties and seeds, possibly based on simulation modeling (Barbottin et al, 2005) and knowledge sharing among different actors, including farmers, users and consumers.

Although this trend has been initiated in developed countries, the overall globalization of markets is increasingly pushing this issue in developing countries seeking to cater to the needs of specific market niches in the high or middle income countries.

2.3.1.6. The need of a renewed design and distribution of roles.

During the past 50 years, a first division of work assigned seed production and agricultural production to different sets of actors. It resulted in a linear innovation process wherein standardization and scale economies for breeders and seed producers were paramount. Moreover, the rigidification of IPR, access and benefit sharing laws and other forms of controls over access to genetic resources for food and agriculture weakened the exchange of genetic resources among breeders who developed new industrial strategies based on strengthened intellectual property arrangements and the increased use of gene technologies. Attempts to balance IPRs with farmers and national rights on genetic resources adds to hyperownership.

This model progressively reveals shortcomings, congruent with the ecological and social consequences of agricultural productivism, at regional and international level. The International Treaty is the first major international policy that attempts to proactively address the situation by creating a form of international germplasm exchange and research commons. On one hand, in developing countries, Millennium goals are not being met, on the other, in developed countries or emergent economies, food markets require a wide range of diverse qualities (see 2.3.3.). This assessment questions the former separation between researchers and producers and calls for an increased role of user’s knowledge in the design of innovation. Hence local arrangements should be promoted (see 2.1.5.).

### *2.3.2. Pest management*[3]

The history of pest management can be read by means of two major competing narratives. One narrative is that intensive agriculture and of the Green Revolution, in which synthetic chemical pesticides and fertilizers play a major role. Another narrative, epitomized for the public by "Silent Spring" (Carson 1962), points to the environmental and human health harms that have been associated with chemical pesticide use and argues for agro-ecological alternatives such as organic farming, biological control and ecological pest management. Integrated pest management (IPM) emerged as a middle ground in which diverse actors respond to the technical and socio-political challenges posed by these two narratives.

Each of these approaches to pest management is upheld by different institutional structures, social actors, and power relationships. The pros and cons of synthetic pesticides are still hotly debated. Concurrently, concern for environment and human health is driving policy (for example, in the EU, India) and technologies toward pest management strategies that seek to reduce synthetic pesticide risks and use. However, the worldwide sales of synthetic pesticides are actually increasing, indicating that considerable barriers exist to achieving necessary changes.

INSERT BOX 2.11 HERE

2.3.2.1 The rise of synthetic pesticide narrative

*Key Message:* Chemical control has advanced production and food security goals significantly, without real controversies during decades, until the 70's. However, serious environmental, health and social justice concerns have been raised since then. Lessons learned resulted in the strengthening of regulatory control and education of users towards sustainable practice. Currently, the use of synthetic pesticides is widespread, backed today like in the past by the economic power of industry, which is a major player in the regulatory, research and extension arenas.

*Drivers of synthetic pesticide use in industrial countries.* Northern industrial countries in the 1950s experienced tremendous structural and institutional changes associated with its adoption of a production-oriented model, that required labour for the post-war reconstruction of nearly all the industrial ; sectors. They sought to maximize food and fiber production, increase efficiency and reduce labour requirements in agriculture. Mechanization and intensive use of external inputs were seen as solutions to these challenges (subchapter 2.1 and 2.2; Fig. 2.11). Synthetic chemical pesticides in the 1950s yielded immediate and significant production benefits (Dayanatha & Chand 1999, Austin 1998, Warren 1998, Webster et al 1999, Zakharenko 1975, Kierukhsky & Kashirsky 1975, Chenkin 1975, Whitford et al. (2006), Anon.1993, Bhowmik, & Prasanta 1999, Tanner et al. 1991, Kanampiu 2003,Armitage & Brook 1976) driving the continued use of such technologies (Evenson & Gollin 2003a, Gill 1995, Repetto 1994, Fan et al. 1998, Sharma & Poleman 1993), and

[3] Broadly speaking, the purpose of agricultural pest management is to protect cultivated plant and reared animal species from the harm caused by insects, competing plants (weeds), disease organisms (fungi, bacteria), etc., that would otherwise exceed economically, socially or environmentally acceptable levels .

soon became the primary pest control method (Shennan et al., 2005; Lighthall, 1995) in intensive agriculture.

INSERT FIG. 2.11 HERE

The emergence of the synthetic pesticide industry had its roots in US and German chemical research, before and after both world wars, and was initially driven by formal inter-agency collaboration between military and public sector chemists and entomologists (Russell, 2001). Since the post-WWII era, industry has played a direct role in product development, formulation, distribution, marketing and advertising (Dinham, 2005; Kroma and Flora, 2003). Industry research and development budgets for the top six multinational pesticide corporations totaled US$2.23 billion in 2004 alone (Phillips McDougall, 2003), over ten times that of the 16 CGIAR research centers' annual 2003 budget combined (CGIAR, 2003).

In the 1990s, the pesticide-biotech industry formed new partnerships with university research and government agencies. While several cash-strapped universities welcomed the new funding flows, the "corporatization of universities" (Bok, 2003; Clark, 1998; Noble, 1977) sparked intense public and institutional debate about erosion of academic freedom, conflict of interest and conflict of mission (Busch et al., 2004; Jennings, 1997; Ten Eyck and Rudy, 2004). Industry has also shaped public policy-making on pesticides through placement of representatives in influential positions in public agencies (CAP and OMB, 2004; Ferrara, 1998; Hardell et al., 2006; Mattera, 2004; Shulman, 2006; UCS, 2004).

Whether or not industry influence in universities and government extension and regulatory agencies is deemed appropriate and beneficial to society at large, the result of the "triple helix" of university-industry-government relations (Etzkowitz, 2003) reflects a significant asymmetry of power in resource allocation and decision-making (Kleinman and Vallas, 2001; Krimsky, 1999). These asymmetries have supported the dominance of the chemical control narrative over other less endowed pest management interests.

Farmers typically have received pest control advice through top-down information distribution channels, by industry salespersons, crop protection services, extensionists or (in the US) Pest Control Advisors (PCAs). Surveys of US farmers indicate that state extensionists' advice advocates chemical-intensive approaches and, while useful in fine-tuning, such control has not met the needs of farmers seeking alternatives to synthetic chemicals (Anderson, 1990; Baker, et al. 1987; Blobaum, 1983; FAWG, 2001; OFRF, 1998; Paulson, 1995; Shennan et al., 2005). However, the introduction and expansion of national regulatory authorities (e.g.1940s Federal Fungicide, Insecticide and Rodenticide Act in USA; 1950s Codex Alimentarius Europaeus; 1970s Environmental Protection Agency in USA) has had significant impact on the use of synthetic pesticides. Consequently, trends by industry are now to develop less hazardous products, new technologies allowing precise application of products thereby reducing wastage, and integrated pest management systems where pesticide use is reduced.

*Drivers of synthetic pesticide use in developing countries.* National and global concerns over food security drove the intensification of agricultural production in the South associated with the adoption of synthetic chemical pesticides, across much of Asia and Latin America (Rosset et al., 2000). The multinational industries, public bodies, and international research and development organizations, played a role in the development, testing, promotion and extension of synthetic pesticides in developing countries. Local pesticide industries have also emerged and are particularly strong now in China, India and South Africa.

The World Food Conference of 1974 highlighted the importance of synthetic pesticides in agriculture. Key public sector actors such as the CGIARs, NARS, the World Bank, USAID and JICA often provided direct or subsidized supplies of synthetic pesticides, typically tying agricultural credit to adoption of input packages that included them (Ishii-Eiteman and Ardhianie, 2002; Holl et al., 1990; Jain, 1992; USAID, 2004). The World Bank's structural adjustment programs often encouraged borrowers to shift production into non-native high value export crops. Since many of these are proved more susceptible to pests than indigenous crops, this frequently resulted in increased use of such pesticides (Clapp, 1997; Hamburger and Ishii-Eiteman, 2003; Hammond & McGowan, 1992; Korten, 1995; Oxfam, 1995).

Agricultural education and training provided through NARS in Asia and Latin America focused on "modernization" and adoption of external inputs, and farmers were routinely advised to abandon traditional pest management practices; direct state intervention in some cases enforced pest control through calendar spraying regimes and many states established pesticide distribution systems to ensure uptake of GR inputs (Meir and Williamson, 2005). Pest control messages were provided to farmers directly by pesticide salespersons and through top-down extension systems such as the World Bank's Training and Visit model.

Pesticide imports and use especially on exported food crops increased in Africa as well, promoted by bilateral aid and lending agencies' provision of pesticides and policy supports during the 1970s and 80s (Clapp, 1997; Hammond and McGowan, 1992). Crop protection  companies expanded markets in West Africa in the 1990s, aided in some cases by World Bank partnerships (Rhone-Poulenc Agro, 1998) and by World Bank-facilitated industry-government contracts to demonstrate pesticide products (e.g. in seven West African countries; FAO, 2001b). In addition, hidden policy supports such as tax or duty exemptions for pesticides still exist, bilateral donations continue, and informal pesticide trading is widespread (Gerken et al., 2000; Mudimu et al., 1995; Macha et al., 2001; Williamson, 2005; FAO/WHO, 2001).

Local pesticide production and distribution companies have grown rapidly in many countries, often producing cheaper but more hazardous pesticides (Pawar, 2002).  In some cases, government extension personnel work also as pesticide distributors (Rahman, 2003; Williamson, 2005,;Pemsl, et al. 2005). As in industrial countries, the central issue here is the power asymmetry of, in this case, powerful and well-resourced government ministry-industry-donor (or development agency) partnerships that encourage farmers' adoption of chemical control measures.

*Impacts of synthetic pesticide use.* The significant yield gains and achievements in food security obtained in many countries have been closely linked to the use of synthetic pesticides and other inputs (Evenson and Gollin, 2003a; Lipton, 2005; subchapter 2.1). Widespread famines and devastation of crops from outbreaks of disease and pests were prevented (Kassa et al. 2001), quality of food produced increased as fungal toxins (Ragsdale et al. 1991, Chulze et al. 1987, Gong et al. 2002,) and harmful plant alkaloids produced in response to pathogen attack were reduced (Kvien et al 1993, WHO 2005, Gray and Hammitt 2000), significant economic losses owing to weed infestations were controlled (Yancy & Cecil 2005, Bridges 1992), animal health and welfare have been significantly impacted where such diseases as trypanosomiasis carried by the tsetse fly can be controlled (WHO 1990, Kamuanga 2001, Singh 1983, Windsor 1992).

The use of synthetic pesticides is calculated to have tripled between 1950 and 2000 but the amount of land used increased by only 10%.  World food production has increased by 25.4%, population by 15.4% between 1990 and 2000 but land use has increased by only 0.66% (FAOSTAT data 2004). Meanwhile, as with other successful control measure (breeding resistance varieties [Aubertot et al. 2006], hand weeding [Spencer 1983, Barrett 1983 ]) resistance to products developed and depended on the mode of action of the pesticide and the frequency of its use. Evolution of pesticide resistance has been thoroughly documented in the scientific literature. By the late 1990s, 2,645 cases of species-to-product resistance had been documented, for 310 chemical pesticides and 540 insect or spider species  (MSU, 2000; Bills et al., 2003). Herbicide, fungicide and bactericide resistance has rapidly increased over the past 20 years, during which time 180 weeds and 150 fungi and bacteria developed resistance (Georghiou, 1986; Vorley and Keeney, 1998; Pretty, 1998) and Aubertot et al (2006) point out that pests have evolved resistance to other non-chemical methods of control as well.

Environmental and human health effects of pesticide exposure (because of lack of efficient training, accidents, misuses) have been widely documented in the scientific and medical literature, and shown to affect entire rural communities (reviewed in Pretty and Hine, 2005 and Kishi, 2005; see also chapter 3). Social and environmental justice concerns have been raised regarding the inequitable distribution of the benefits of chemical control (largely accruing to better resourced farmers and industry) and its harms (falling disproportionately on the poor and disadvantaged, as well as on the "ecological commons;" Oayum and Sakkiari, 2005; Reeves et al., 2002).

2.3.2.2 Institutional responses to pesticide impacts concerns.

Civil society responses. Many civil society networks have emerged that target pesticides or promote alternatives to specific pesticides, such as the Pesticide Action Network comprising 800 organizations in 100 countries. Others have spun out of UN processes, such as the International POPs Elimination

Network (IPEN) and the Methyl Bromide Alternatives Network (MBAN). The International Union of Food workers (IUF), a federation of 336 trade unions in 120 countries representing 12 million workers, has frequently organized to safeguard the health of workers involved in the production and use of pesticides.

These organizations, along with consumer and local advocacy groups, have raised public awareness about environmental and health hazards associated with pesticides; pushed for stronger regulatory responses at local, state, national and international levels; encouraged industry to withdraw its most toxic products and abide by the FAO's Code on the Distribution and Use of Pesticides; and called for more political and financial support for the research, development and extension of ecological alternatives. Civil society organizing has emerged as a powerful force, not just in the West, but also in the global South (e.g. India, Thailand, Ecuador, Philippines and Brazil). Civil society and many independent researchers (as well as FAO, ILO, WHO and some governments) have interpreted the negative impacts of pesticide-reliant agriculture as a social justice issue and have called for a rights-based approach to agricultural development, that explicitly recognizes rural communities' rights to good health and clean environments. NGOs with social justice, environmental and health causes now have significant influence in government and international bodies. This raises significant but unresolved questions of the role of civil society in governance(Cohen 2003, Matthews 1999); accessing financing larger than the entire UN system they have begun to penetrate deeply into official decision making (Matthews 1999).

*Government and inter-governmental responses.* Governments have responded to accumulating evidence regarding negative environmental and human health side effects of synthetic pesticides (reviewed in Pretty and Hine, 2005; Kishi, 2005; see also chapter 3) with legislation, regulatory frameworks and policy initiatives, including international treaties and agreements (see Box 2.12). The OECD Pesticide Risk Reduction Project was initiated in 1994 to promote pesticide risk reduction (OECD, 2006), and several European countries undertook Pesticide Use Reduction Programs (Williamson and Buffin, 2005) Maximum residue levels (MRL) regulations for pesticides in food [e.g. 69% of food in UK has no pesticide residues (Brown 2004)] have been established at government level as well as internationally (see 2.3.3.).

INSERT BOX 2.12 HERE

The UN FAO Code on the Distribution and Use of Pesticides (adopted at the 1985 FAO Conference, revised in 2002) contains key standards to 'ensure that pesticides are used effectively and efficiently for the improvement of agricultural production, and of human, animal and plant health.' (FAO, 2002).. Compliance, however, has been weak and environmental and health standards actually deteriorated during its first ten years (FAO, 1995a). The revised Code focuses not only on minimizing hazards associated with pesticide use, but also on promoting ecologically-based IPM. The major multinational crop protection companies helped developed and promote the Code, and publicly re-endorsed the revised Code in 2003.

The World Bank established its first policy on pesticides in 1984 in response to civil society pressure after the explosion of a pesticide plant in Bhopal, India. The Bank's subsequent policy stated that it assists borrower countries in "reducing reliance on chemical pesticides" and promotes ecologically-based IPM (World Bank, 1998a). External and internal reviews of World Bank lending have found policy implementation weak (Ishii-Eiteman and Ardhianie, 2002; Karel, 2004; Tozun, 2001; Sorby et al., 2003; Liebenthal, 2002), but recent evidence suggests compliance is improving (Karel, 2004). An external audit attributed the World Bank's difficulty in implementing its policy to its practice of "actively open(ing) the door" to pesticide companies through programs geared towards modernization of agriculture, liberalization and privatization (FAO, 2001a).

*Multinational industry responses.* Recognizing the need to improve awareness of the hazards and improve effectiveness of synthetic pesticides in developing countries, the Global Crop Protection Federation, an industry association now named CropLife International, launched 'safe use' campaigns to train hundreds of thousands of farmers in the use and handling of pesticides, and to ensure that compounds are used in a way that is consistent with the national regulatory framework (CropLife 2005b, Syngenta, 2003). The efficacy of these pesticide use training programs is disputed, with some sources reporting considerable success (Grimaldi, 1998; Tobin, 1996; Syngenta, 2006, Atkin and Leisinger 2000) and other sources concluding that these programs have not resulted in reduced poisoning incidence, and sometimes have had opposite effects (Kishi et al., 1995; McConnell & Hruska, 1993; Murray, 1994; Murray and Taylor, 2000).

Industry has invested in research and development of lower dose and more selective pesticides, improved formulations and packaging, new application technologies, improved techniques and services, and resistance management strategies (Syngenta Crop Protection US, 2006). It has formed Resistance Action Committees comprising industry and academic representatives who monitor pesticide resistance and devise techniques to assist advisors and growers in implementing resistance management practices (Jutsum et al., 1998). Multinational companies continue to research more precisely targeted, less toxic products and improved means of delivery (Harden 2000) to counter the problem of older (out of patent) more highly toxic products manufactured by domestic producers (EJF, 2002; Pawar, 2002).

Integrated Pest Management and sustainable agricultural techniques have been supported and funded by the industry internally and with academic and developing country stakeholders (CropLife 2005a, CropLife 2003, CropLife 2006). One such example is the APCOT (Andhra Pradesh partnership) program set up for Indian cotton farmers, and a partnership between local NGOs, Syngenta and the farmers.

*Multistakeholder partnerships.* Multiple stakeholder initiatives have also emerged, such as the Africa Stockpiles Project. This project, initiated by PAN and WWF in 2000, tackles the hazards and risks posed by obsolete stockpiles of pesticides. FAO is the lead actor providing technical assistance to clean up stockpiles and has called on donor agencies to assist. CropLife International, representing the agrochemical and plant science industry, has also participated in the program since its inception, and has provided funding and technical assistance, for example in Ethiopia, Pakistan and Madagascar.

2.3.2.3 Biological and ecological pest management as alternatives.

*Key Message:* Biological and ecological pest management offer environmentally robust alternatives although consistently high agricultural productivity still has to be demonstrated. However, public and private sector understanding of, and investment in these holistic approaches has been limited. Environmental benefits are clear but their implementation asks for radical changes in the production systems, and partial application shows controversial results. Moreover, the social and institutional challenges around equity and scaling-up have not been well studied.

*Biological and ecological pest management*. Biological approaches to pest management emphasize the ecological and evolutionary relationships between pests and their natural enemies and encourage increased predation, parasitism or disease of the pest organism, increased resource competition and mating disruption (Shennan et al. 2005). Classical biocontrol involves identification, collection, mass-rearing, transport and release of natural enemies (parasites, predators or pathogens) into the field, and can include introduction of exotic natural enemies (NE) or augmentation of local NE populations to reduce pest pressure (DeBach, 1974). Conservation biocontrol involves the manipulation of the agro-ecosystem and landscape to create favorable year-round conditions for natural enemies (Jervis et al, 1993; Doutt and Nakata, 1973; Idris and Grafius, 1995; Kalkoven, 1993; Murphy et al., 1998; Ricketts, 2001).

Ecological pest management (EPM) encompasses not only biological control, but also many other ecological and cultural practices that focus on strengthening the health and resilience of the entire agro-ecosystem (Altieri, 1987). It relies on scientific advances in the ecological and entomological fields of population dynamics, community and landscape ecology, multi-trophic interactions, and plant & habitat diversity (reviewed in Shennan et al, 2005).EPM is a less-known, albeit growing, approach to pest management.

*Drivers of biological control.* Recognition of the ability of natural enemies to bring a number of serious economic pests under permanent control stimulated the implementation of major biocontrol programs in the US in the 1920s (Hagen and Franz, 1973). The rapid rise of chemical control after WWII, however, reduced interest in biological control in industrial countries, although the development of induced resistance in the 1950s, and recognition of risks and undesirable side-effects associated with pesticides, revived interest in Europe, leading to the establishment of the International Organization for Biological Control (IOBC) in 1955, and successful application of biocontrol in Western Europe

(Greathead, 1976; van Lenteren et al., 1992; Sigsgaard, 2006) and Central and West Africa (detailed below). Institutional support for biological control in the US declined in the 1980s and 90s, owing to proactive industry and state and federal agencies' preference for synthetic pesticide use (Hammerschlag, 2007; Jennings, 1997; National Research Council, 1989).

Growing consumer interest in pesticide-free produce helped establish a small but thriving biocontrol industry in industrialized countries (Dent, 2005). Worldwide, over 150 natural enemy species are currently marketed for biocontrol; in 2000, about 85 commercial producers of biocontrol agents accounted for US $50 million in sales, reflecting an annual growth of 15-20% (van Lenteren, 2006). The plant science industry has supported biological control since 1979 and most major companies have invested in biopesticide research at one time. In contrast and a limiting factor to its use, ecological pest management and conservation biocontrol do not produce products that can be widely or mass- marketed, as they need to be adapted to specific crop-insect ecologies. They have therefore attracted little interest from the public or private sector. An alternative driver of equal power to market forces has not yet been found although informed citizens and consumers have begun to provide feedback and countervailing force that has influenced pest management policy and practice.

*Impacts of biocontrol and EPM*. Achievements, impacts, shortcomings and new opportunities in classical biocontrol have been assessed at length elsewhere (Greathead et al., 1971; Greathead and Waage, 1983; Greathead 1989; Greathead, 2003; Herren, 1990; Neuenschwander and Markham, 2001; Neuenschwander et al. 2003; Zimmermann and Olckers, 2003, Samways 1988, Howarth 1991).

Lack of attention in the 1970s to quality control procedures contributed to a number of biocontrol failures later understood to be caused by changes in rearing and transport methods (van Lenteren, Bueno 2003). Little environmental harm has been linked to invertebrate biological control of insect pests and weeds, and its safety record is established (Hokkanen and Hajek, 2003; McFadyen, 1998; van Lenteren et al., 2003; 2006; Wajnberg et al., 2001; Wilson and McFadyen, 2000) with the exception of several failures associated with vertebrate introductions. Ecologists have raised concerns regarding potential impacts on non-target organisms (Simberloff and Stiling, 1996; Strong, 1997). These have been little studied to date—with the exception of potential impacts of plant-feeding biocontrol agents on related crops, for which rigorous screening protocols exist—and merit closer attention (Hopper, 2001; Strong and Pemberton, 2001).

Biocontrol has had negative impacts where ecological knowledge or management has been insufficient to prevent ecological damage (Louda et al. 1997, Strong 1997, Boettner et al. 2000, (Williamson 1996, Samways, 1997), and has led to the extinction of species in some countries (Samways, 1997). It will be important to manage biocontrol against the aims of biodiversity and conservation to which many countries have signed up (Samways, 1997), improve consistency of effect and reduce ecological hazards (Turner, 1984, Delfosse 1985; Howarth, 1991).

*Role of institutional actors.* Successful biocontrol systems have required public sector investment, political commitment to maintain and adequately finance research, breeding and release programs, close coordination and collaboration between technical and regulatory agencies and donors at national and regional levels, and a least-toxic approach to pesticide use to create a safe environment for biocontrol agents (Neuenschwander, 1993). Where such commitments have existed (e.g. Kazakhstan, post-Soviet Cuba, Nigeria, Benin, Togo and several other Central and West African countries) biocontrol programs have been important contributors to agricultural production and national food security (Rosset and Benjamin, 1994; Neuenschwander, 1993; Pretty, 1995; van Lenteren, 2006).

Much of the science underpinning ecological and biological pest management has been developed by entomologists and ecologists working within universities and national, regional and international institutes. For example, the Nairobi-based International Center for Insect Physiology and the Environment (ICIPE), the International Institute of Tropical Agriculture (IITA), the Commonwealth Agricultural Bureau Institute (CABI), the International Organization for Biological Control (IOBC), and the International Institute of Biological Control (IIBC).

Technical and administrative staff have played a key role in designing and maintaining complex and extensive networks of collaboration between these institutes and other key actors; for example, the Inter-African Phytosanitary Council (IAPSC) of the Organization for African Unity, CIAT in Colombia and others. FAO, UNDP and donor agencies such as GTZ and the UK Natural Resources Institute (NRI) have until recently, provided essential institutional support, including financing, advertising and stimulating the establishment of national biological control programs in Africa in the 1980s and 90s (evaluated by Herren, 1990; Neuenschwander, 1993; Neuenschwander et al. 2003; Wodageneh, 1989). Growth of entomology and biocontrol departments in Latin America in the 1970s stimulated adoption of biocontrol practices across the region, particularly in Brazil and Mexico, while the collapse of the Soviet Union and subsequent elimination of pesticide subsidies drove Cuba’s conversion to biocontrol (Altieri and Nichols, 1999; van Lenteren, 2006; van Lenteren and Bueno, 2003).

In response to observed shortcomings in biocontrol breeding and release practices in the 1990s, the IOBC and EU developed production guidelines subsequently taken up by the International Biocontrol Manufacturers Association (IBMA). A growing number of countries now use the IOBC and IBMA guidelines (Australia, Brazil, South Africa, Japan, New Zealand, India; van Lenteren, 2003). As far as release of biocontrol agents is concerned, the FAO, IIBC and IOBC developed a voluntary Code of Conduct for the Import and Release of Biological Control Agents, to strengthen capacity of national regulatory bodies and public and private producers to “facilitate the safe import and release of biological control agents” (Waage, 1996).

The ability of several key actors and institutional arrangements to work effectively together enabled the scientific and technological processes associated with biocontrol in subsistence crops to meet societal needs, particularly well illustrated by ICIPE, IITA, IIBC and others’ dramatic successes in Central and West Africa (Neuenschwander et al. 2003; Maredia and Raitzer, 2006). However, the expansion of several proposed biocontrol projects in Africa is still limited, which claims for further research about the efficiency of research investments, the governmental capacity and the economic attractiveness of the available technical package .

*Contribution of biocontrol to IAASTD goals*. The CGIAR meta-analysis shows that classical biological control can provide a cost-effective and sustainable option for reducing economic and environmental losses from pests (Alene et al., 2005). The CGIAR study underscores the value of taxonomy and ecology, two of the scientific fields most directly responsible for the technical success of the projects, and the importance of securing high levels of institutional commitment, willingness to form and maintain complex inter-agency networks, and an openness to learning (Neuenschwander, 1993). European (German, Swiss, Austrian) donor support was essential.

Impact analyses of ICIPE's biologically-based plant, animal, human and environmental health projects in Africa indicate significant contributions across a range of economic, social and environmental criteria, including reduced pest and disease incidence and damage, improved food security, enhanced community self-organization, improved agricultural, income-generating and entrepreneurial skills and reductions in negative pesticide-related side effects (ICIPE, 2006).Several papers have identified positive socio-economic impacts of ICIPE and IITA's biocontrol work in Benin, Kenya and Togo (Bokono-Ganta et al., 2002; de Groote et al., 2003; Löhr et al., in press; Macharia et al., 2005; Macharia et al, in press; Moore, 2004; Norgaard, 1988; Zeddies et al., 2001). These studies found high benefit-cost ratios (from 24:1 to 149:1) including all institutional inputs, high internal rates of return (over 80%) and important socio-cultural benefits (e.g. non-hazardous protection of mango trees affected entire communities' use of trees for shade, public gatherings and food).

The Convention on Biological Diversity raises important issues for institutions engaging in biocontrol: how to ensure equitable and fair sharing of resources, research and benefits among actors and countries (Waage, 1996). Evidence suggests that industrial countries have benefited more than Southern countries with respect to the transfer of biocontrol agents. (Altieri, 1991; Altieri et al., 1997). Furthermore, when biocontrol has been implemented as a form of input substitution in monocultures, rather than as management of robust agro-ecosystems (EPM), it has failed to address the sustainability, equity, and profitability of small holder farming (Altieri et al. 1997; Rosset and Altieri, 1997).

Scientists experienced in biological control argue that greater public and private sector investment in institutional capacity could dramatically increase farmers and states' ability to capitalize on these alternatives approaches without compromising health and environmental goals (Hammerschlag, 2007; Neuenschwander, 1993; van Lenteren 2006; Waage, 1996). But they would have to ensure that the approaches go beyond input substitution and address equity and broader social and agroecological imperatives (Altieri, 1991; Altieri et al., 1997).

2.3.2.4. Integrated pest management.

*Key Message:* Integrated Pest Management (IPM) rests on the combination of several pest control tools and strategies. In its modern form, it arose in response to the challenges posed by conventional chemical controls and the rising demand for safe and sustainable agriculture. The evidence shows conclusively that IPM can deliver high yield, under a range of production conditions, while reducing input costs and avoiding environmental and health hazards. IPM has come to be supported by a large and diverse constituency, including many farmers, NGOs, policy makers, government bodies, multinational plant science industry, CGIARs, FAO, and the World Bank. Adoption has been limited in some countries; further policy reforms and further investments in farmer training and education could overcome existing constraints.

*What is IPM?* Integrated Pest Management as an indigenous pest management strategy has been practiced over many generations by farmers. In its modern form, it emphasizes a conscious shift towards management (rather than control) of pest populations by use of a diversity of methods.

The FAO definition is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. Such a practice is highly knowledge intensive (Dreyer, 2005).

*Drivers of IPM in the North.* The emergence of IPM in industrialized countries has been driven by concern for human health and the environment, development of pest resistance to pesticides, pest replacement and resurgence caused by inappropriate use of pesticides (AgLearn, 2005, Dent 2005), consumer desire for low or no pesticide residues in food (Williamson and Buffin, 2005), improved pesticide product life cycle management and the recognition that improved management is necessary (CropLife, 2003). Policy commitment to national IPM programs encouraged adoption, particularly in Europe where goal-oriented programs with benchmarks for reduced pesticide use have been implemented[4] (Fig. 2.12). Several US agencies have also adopted IPM policies, but implementation tends to emphasize pollution mitigation strategies over preventative approaches to ensuring crop health, while funding to implement the policies and to staff the technical assistance components has been limited (Brewer et al., 2004; CA Al-Babili P, 2005; Hammerschlag, 2007; GAO, 2001; NRCS, 2001).

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Agri-food companies such as Unilever; food processors (e.g. tomato paste, coffee, cacao/chocolate); and some food retailers (Williamson and Buffin, 2005; FAO, 2001a) have taken steps to source produce from suppliers using IPM or low-to-zero pesticide inputs, not only to meet consumer preferences and regulatory requirements but because it reduces the costs to their businesses. Labels

[4] For example, the European Group for Integrated Pest Management in Developing Assistance (IPM Europe) in 1993 has led to widespread support of IPM in the EU member states. See the UK's Entry-Level Stewardship Programme.

identifying IPM or low-pesticide production methods (e.g. Certified Organic, Wisconsin “Healthy Grown” potatoes, Belgium “Fruitnet”) and many other successful market-oriented collaborations (IATP, 1998) have encouraged growers to adopt these practices. Local food systems (community-supported agriculture programs, farmers’ markets, etc.), many of which feature low-to-zero pesticide input produce, also offer a small but growing alternative to conventionally grown cash crops (Williamson and Buffin, 2005).

*Innovation in North.* Some IPM practices emphasize a transition towards biological and cultural methods (refs). Others focus on pest scouting and fine-tuning of pesticide applications (refs). As ecological understanding of pest population dynamics has grown, so too has recognition of the importance of adapting IPM practices to local conditions.

Innovations in institutional arrangements have ranged from conventional public-sector led programs (e.g., Canadian Pesticide-Free Production, Nazarko et al., 2002) to farmer-led participatory research (e.g., Belgian fruit growers; Nazarko et al., 2002). The success of Wisconsin Healthy Grown potatoes was rooted in a strong partnership between growers, environmentalists and formal researchers. Companies such as Unilever, the Co-op and Campbell developed their own ability to work with growers, including thousands of small holders in developing countries (Williamson and Buffin, 2005; FAO, 2001a). In Central and Eastern Europe (CEE), the Global IPM Facility’s Farmer Field School approach has been tested in at least eight countries and is enabling a growing number of farmers to manage major maize pests using IPM methods, with considerable success (Jiggins et al., 2005).

Research within the industry is put into practice with farmers, informing on optimal strategies, technologies and products suitable for IPM and in the last decade the industry has formed partnerships with many stakeholders to foster IPM (CropLife, 2003).

*Drivers of IPM in the South.* The spread of IPM in the South has had various drivers:  the high incidence of pesticide poisonings among farmers and farm workers (Holl et al., 1990); growing indebtedness and other economic problems associated with smallholder farmers’ reliance on purchased inputs; new markets spurred by consumer demand for pesticide-free produce in the North (IFOAM, 2003; Ton, 2003; Martinez-Torre, 2006) and in countries with growing middle class populations (e.g. Thailand, China, India); national recognition of the economic costs of pesticides (see Box 2.13); and international attention to sustainability issues (refs-UNCED). European MRLs have provided a further incentive to develop IPM options.

FAO’s paradigm-shifting work in Asia in the late 1980s provided (a) the scientific basis that pesticide-induced pest outbreaks were, at times, responsible for crop failures in rice; (b) the ecological evidence that reduction of  pesticides uses would positively affect yields and system stability; and (c) the policy insight that a number of directives (e.g., ban of selected pesticides, removal of pesticide subsidies and national support for IPM) could transform the situation, as it did in Indonesia (Kenmore et al., 1984;

Settle et al., 1996; Gallagher, 1999; Box 2.13).

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*Innovation in South.* Participatory field-based educational processes in pest management gained strength in the 1980s (Röling and Wagemakers, 1998, CropLife 2003, Syngenta Foundation). IPM training and education programs that utilize non-formal education methodologies and build on, rather than aim to replace, farmers' traditional knowledge, have been shown to have longer lasting success in farmers' adoption of and innovation in AKST, than training methods that disseminate fixed instructions for input use and pest control (Mangan and Mangan, 1998). The IPM Farmer Field School (FFS) methodology pioneered in Southeast Asia typified this knowledge process and was subsequently adapted by governments, NGOs and farmers' associations for use not only in IPM but also in combating community health problems such as AIDs (Gallagher, 1999). As such, IPM in this context has evolved from the classical and purely technological insect management approach (which includes classic biological control) towards one in which the focus is on education and social change, whereby farmers develop the scientific research skills to test hypotheses and manage pest populations in their fields (and at landscape and district levels) on the basis of ecologically informed decision making (Matteson, et al., 1994; Ooi, 1998).

*Impacts of institutional innovations in IPM.* Evidence, particularly in rice production, shows that IPM can lead to pesticide reduction without yield loss (Eveleens, 2004; Heong & Escalada, 1998; Mangan and Mangan, 1998; Barzman and Desilles, 2002). Yield advantages of IPM have been particularly strong in the South, and thus have significant policy implications for food security in developing countries (Pretty, 1999; Pretty, 2002, Pretty et al., 2003). The community-wide economic, health and environmental benefits of farmer-participatory ecologically-based IPM have been widely documented (Braun, 2006; Braun et al., 2006; Mancini, 2006; Ter Weel and van der Wulp, 1999; van den Berg and Jiggins, 2007). Emergence of local leadership (Dilts, 1999) and farmers' active role in community-wide innovation processes following participation in IPM farmer field schools (Pontuis, 2004), suggests wider social benefits (Mancini et al., 2007). Large-scale impacts on social equity have not yet been assessed.

Difficulties in measuring the cost-effectiveness of large scale IPM projects have in some cases impeded large scale adoption (Kelly, 2005). One economic analysis suggests the knowledge-intensive methodology of IPM Farmer Field Schools is fiscally unsustainable as a national extension approach (Quizon et al., 2000). A recent meta-review of 35 published data sets on costs and benefits substantiates FFSs' effectiveness as an educational investment in reducing pesticide use, helping farmers to make informed judgments about agro-ecosystem management, and contributing to farmer empowerment (van den Berg and Jiggins, 2006). The available evidence (on www.FarmerFieldSchool.net) demonstrates the need for more impact assessments and the opportunities for further experimentation in the occupational education of farmers in relation to pests and agro-ecosystem management.

*Constraints to adoption of IPM.* Economic, social, and political roadblocks—including economic competition, government instability and weak regulations; deficient extension services and inadequate financing of IPM; and socio-economic stratification—has prevented adoption of IPM on a large scale in some countries (Altieri, 1999; Holl et al., 1990; Rodriguez & Niemeyer, 2005; Shennan et al., 2005). Continuing contraction of the public sector, dwindling donor support for agriculture in general, and agricultural ministries' attachment to demonstration-package of external inputs has constrained further scaling-up of participatory, field-based IPM programs (Sherwood, 2006; Williamson, 2005). As a result, in Africa as in Latin America, communities are exploring self-financing mechanisms for IPM field schools (Okoth, 2003).

*Response from actors and arrangements in IPM.* A growing number of bilateral donor agencies have been investing in ecological IPM strategies (e.g., Netherlands, Denmark, Italy, Sweden, France and occasionally in the past also USAID); the US has weakened its support and funding for domestic IPM programs and in overseas aid (Hammerschlag, 2007). The Global IPM Facility, FAO and EU have provided considerable technical and policy assistance to countries seeking to develop national IPM programs and to establish favorable policy environments.

The private sector has also developed and promoted IPM programs, with widely varying approaches to pesticide use. Industry IPM programs focus on assisting farmers in making judicious use of all available tools of pest control. Emphasis is placed on pest management, and when pesticides are needed the use of less hazardous, lower dose and more selective pesticides, improved formulations, new application technologies, and resistance management strategies (Syngenta Crop Protection US, 2006). Numerous examples exist in the literature of industry funded initiatives and direct participation in IPM programs (Pawar 2002, Ellis 2000, CropLife 2003, Dollacker 2000 , Ebner 1982, Syngenta Crop Protection 2006, Dollacker, 2000) and in the developing world it is reported that pesticide consumption in India declined by 25 metric tonnes between 1995 and 2000 (Pawar 2002).

Food industry actors, driven by a need to reduce costs and meet consumer demands, have focused on minimizing or eliminating pesticide use. Sysco, a $30 billion food service company, requires vegetable growers for its processed food market to implement IPM (Hammerschlag, 2007). Likewise, Unilever, Del Monte and General Mills have encouraged their producers to adopt IPM practices. Campbell Soup Company's IPM project in Mexico, for example, eliminated all (99.9 percent) pesticide applications in tomatoes without suffering any loss in either yield quality or quantity: no synthetic pesticides were used on its 4,000 acres and insect control was achieved through use of pheromones and bio-insecticides (Annex B4 in FAO, 2001).

A variety of collaborative efforts, more recently, have focused on encouragement of biodiversity in response to the environmental, economic and social concerns arising from pesticide use. They typically include industry, NGOs, academic institutions and farmers : e.g., UK's England Rural Development Program, Project Bumblebee and SOWAP (SOil and WAter Protection) (Syngenta 2005), a collaboration between Earthwatch, RSPB, Unilever and DEFRA, The Farmed Environment Company, The Center for Ecology and Hydrology and many others, addressing respectively conservation agriculture and insect biodiversity..

2.3.2.5. Policies and trends

Pest management approaches over the past 60 years have responded to a complex combination of technological, social, political and institutional factors. The prevalence of the use of synthetic pesticides today reflects i) the successful aspects of the approach and strong market signals, ii) the significant political and economic influence of business actors (CAP and OMB, 2004; Dinham, 2005; Ferrara, 1998; Hardell et al., 2006; Mattera, 2004; Shulman, 2006; UCS, 2004) and iii) a classical phenomenon; path-dependency which stresses that a given firm (or farm) has accumulated equipments,

Health and the environment have been moving up the policy and action agenda, in industrialized and many developing countries especially over the last 20 years. However, few if any countries have consistent policies across their health, food, agriculture, science, trade, and environment ministries. The balance of advantage and disadvantage among the range of pest management options is viewed differently by each of the interests concerned. None the less, the last 60 years has seen significant shifts in understanding and practice, generally speaking in the direction of replacing synthetic pesticide approaches by IPM and biotechnological approaches, and in adoption of stronger regulatory and policy frameworks to control synthetic pesticide use. However, since effective pest management necessarily relies on farmer decision making in specific conditions of place and time, attention also has been given as to how to reach millions of small farmers with educational and informational support that would enable them to make the ecologically-informed decisions. This challenge largely remains unmet.

An increasingly powerful driver (particularly in the North, but also in a number of Southern countries) is consumer perception of what constitutes healthy food and concern for the environmental and social justice dimensions of food production. There has been a notable rise in certification and labeling regimes to meet consumers' demand for information about the origins and methods of how their food is produced. Food retailers are responding by insisting on observance of MRLs, and using pesticide residue data as marketing material.

Despite the tightening national and international regulatory environment around pesticides and notwithstanding the documented success of ecological pest management in most crops, sales and use of synthetic pesticides is still growing in developing countries. Despite industry-organized safe use trainings, these trends are still resulting in pesticide-induced pest outbreaks and an unacceptably high level of unintentional pesticide poisonings, mostly but not solely in the developing world (EJF, 2002;

Kishi, 2005).

Genetically-engineered herbicide-resistant and Bt crops were expected by many to reduce the need for and therefore use of synthetic pesticide (see. 2.3.1) and in many cases this is the case (see 2.3.1 Catteneo 2006, Qaim & Traxler 2002, Huang et al 2002a, Traxler et al 2001, Ismail 2001, Huang et al 2003). However, their use is perceived as introducing other environmental hazards (Snow et al., 2004) and while their overall impact on pesticide use is disputed (see 2.3.1; Benbrook, 2004; Pemsl et al., 2005; USDA, 2000 there have been significant benefits for many (Christou and Twyman, 2004, Huang et al 2002b, Catteneo et al. 2006, Qaim & Traxler 2002, Huang et al 2002a, Traxler et al 2001, Ismail 2001, Huang et al 2001, Al-Babili and Beyer, 2005).

2.3.2.6. Ways forward.

The question of how to move forward is strongly contested, and depends on the identity and interests of the proponents. Industry calls for improved products, faster registration of new less toxic products, and more safe use training. Civil society and many leading researchers in the fields of public health, medicine, participatory development and extension, call for the immediate elimination of WHO Class 1 a and b and gradual phase-out of WHO Class 2 pesticides; renewed public sector investment in agro-ecological and organic RDE and education; the establishment of better institutional linkages between farmers, extension systems and researchers in ecology and sociology; and national policy commitments to support system-wide transition towards ecological pest management. Market leaders and innovators in the food industry are already moving ahead towards sourcing reduced or zero-pesticide use products. Many governments have been caught between conflicting interests and pressures, while others are moving forward to meet public interest demands and/or catch market opportunities. Stakeholders—both governmental and nongovernmental—have also called for increased adoption of two key principles to be much more widely adopted in policy formation processes: the precautionary principle and polluter pays principle.

The weight of the evidence points towards the need for more determined support for participatory ecologically-based decision making by farmers, stronger and enforceable policy frameworks and public sector and donor agency investment in sustainable and ecological agricultural research and extension. More experimentation is needed to test innovations that enable further societal shifts towards sustainability.

### ***2.3.3. Food narrative***

Food is an overarching theme, in direct connection with life. The narratives of pest or seed management are assessed in the last analysis on the basis of their ability to feed the world sustainably and equitably. Thus we choose to end this sub-chapter with an assessment of 'food', in terms of safety, security, and sovereignty. The food story is not only a story of scientific endeavors competing for recognition (see Table 2.7). It is a story of the political choices made in relation to AKST. These choices will be even more important in coming decades: the FAO stresses the fact that "the knowledge and resources to reduce hunger are there. What is lacking is sufficient political will to mobilize those resources to the benefit of the hungry" (FAO 2006a).

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2.3.3.1. Food safety

Access to good quality food has been humankinds ' main endeavor from the earliest days of human existence. The safety of food is a basic constituent t of food quality. " It implies the absence or acceptable and safe levels of contaminants, adulterants, naturally occurring toxins or any other substance that may make food injurious to health on an acute or chronic basis (FAO, 1999). The Rome Declaration on World Food Security reaffirmed the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger. The World Food Summit (WFS) thus recognized the intrinsic link between food security and food quality and safety control. Increases in the populations of developing countries, and in urban populations in particular, coupled with problems of environmental and food hygiene, have placed increasing stress on food production, handling and distribution systems in developing countries, leading to potentially serious food quality and safety problems (FAO, 1999).

Approximately 1.8 million children in developing countries (excluding China) died from diarrhea disease in 1998, caused by microbiological agents, mostly originating from food and water. One person in three in industrialized countries may be affected by food-borne illness each year. In the USA, some 76 million cases of food borne illness, resulting in 325 000 hospitalizations and 5000 deaths, are estimated to occur each year. Between 1993 and 2002, 21 Latin American and Caribbean countries reported 10,400 outbreaks of food- and waterborne illness, according to information gathered by the Pan American Health Organization (PAHO) and the WHO. Those outbreaks caused nearly 400,000 illnesses and 500 deaths (CSPI 2005).

*2.3.3.1.1 Origin and historical milestones*

Evidence from the earliest historical writings indicates that governing authorities were already then concerned with codifying rules to protect consumers from dishonest practices in the sale of food. Assyrian tablets described the method to be used in determining the correct weights and measures for food grains, and Egyptian scrolls prescribed the labeling to be applied to certain foods. In ancient Athens, beer and wines were inspected for purity and soundness, and the Romans had a well-organized state food control system to protect consumers from fraud or bad produce. In Europe during the Middle Ages, individual countries passed laws concerning the quality and safety of eggs, sausages, cheese, beer, wine and bread. In 1202, King John of England proclaimed the first English food law, the Assize of Bread, which prohibited adulteration of bread. Regulation of food in the United States dates from early colonial times (Lacie Thrall, 2006). The second half of the nineteenth century saw the first general food laws adopted and basic food control systems put in place to monitor compliance.

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The first attempts to deal with hazardous agents began in the 1940s to 1950s, when toxicologists looked at data on hazardous chemicals, such as pesticides and food additives, and derived limits on exposure in order to protect human health (Rodricks, 2001). In 1954, two Food and Drug Administration (FDA) toxicologists, Lehman and Fitzhugh, published a paper that defined the basis for what is now referred to as the acceptable daily intake (ADI), a level thought to be a threshold intake of a chemical for a very large population of people, below which there should be no significant toxicity risks. In recent years, the conjectured problem of ‘cocktails’ of chemical mixtures ingested with food or water has received increasing attention but decisive regulatory action awaits improvement in diagnostic tools that address this concern.

Based on a 7-step method developed in the 1960s for controlling processed food in the U.S space program, a major step in advancing a science-based food safety system has been the implementation of Hazard Analysis Critical Point (HACP) in various sectors of the food industry. In parallel , the development of “farm to fork” strategies by the industry has extended the notion of quality management along the entire supply chain (Hanak et al., 2002). This movement explains also the recent concern given by some regulatory agencies to the issue of consumer laxity regarding food hygiene, seen as a major source of food-borne illnesses and a public health issue. The efforts made by some leading food industries and regulators to this effect are commendable and should continue (Mol & Bulkeley, 2002).

*2.3.3.1.2. Diagnosis*

*General Considerations/ quantitative data / economic costs.* Food-borne illnesses are prevalent in all parts of the world, and the toll in terms of human life and suffering is enormous. Contaminated food contributes to 1.5 billion cases of diarrhea in children each year, resulting in more than three million premature deaths (WHO, 1999), in both developed and developing nations. In developing countries, food borne diseases are a primary cause of malnutrition, which then affects the growth and disease resistance of infants and children. Each year, between 12 million and 13 million children die from the combined effects of malnutrition and infection (WHO, 2002a). Those who survive may suffer from arrested physical and mental development, being deprived of the chance to reach their full potential in society (WHO, 2002a). In Africa, children may experience as many as five episodes of diarrhea per year and 800,000 children die each year from diarrhea and dehydration (CSPI, 2005).

The data from FDA detention lists for the period July 1996 to June 1997 for food imported from different regions of the world is given in Table 2.8

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At the top of the list stand food hygiene problems represented by contamination of food with insects and rodent filth. Microbiological contamination comes next, followed by failure to comply with US low acid canned food registration requirements, and then labeling. Over 50% of the rejections are attributable to lack of basic food hygiene, and failure to meet labeling requirements (FAO, 1999).

Food contamination creates an enormous social and economic burden on communities and their health systems. The market rejection costs of contaminated commodities, export market losses, sampling and testing costs, costs to food processors and consumers, and of the most important the associated health costs are high. The best estimates of the economic costs of food-borne diseases come from developed countries. In industrialized countries, up to 30 percent of people suffer from food-borne illnesses every year. The incidence of food-borne diseases may be 300 to 350 times higher than the number of reported cases worldwide. Below are some cases in support of the point:

- In 1995, the United States estimated the annual cost of the 3.3–12 million cases of food-borne illness caused by seven pathogens at US $6.5–35 billion in medical costs and lost productivity (WHO, 2002a).
- In the European Union, the annual costs incurred by the health care system as a consequence of Salmonella infections alone are estimated to be around EUR €3 billion(BRF, 2004).
- Iṇ Australia, the cost of an estimated 11,500 daily cases of food poisoning was calculated at AU $2.6 billion annually ( ANZFA, 1999).
- In the United Kingdom, care and treatment of peoplẹ with the new variant of Creutzfeldt-Jakob disease (vCJD) are estimated to cost the health services about £45,000 per case from diagnosis and a further £220,000 may be paid to each family as part of the government's no-fault compensation scheme (DHS, 2001). Pricewaterhouse Coopers estimates the range of economic impacts to the UK from £2.5 to £8 billion (US$3.6 to $11.6 billion), (Mathews, 2001). More details on BSE are discussed under 2.3.3.4.1
- Analysis of the economic impact of a *Staphylococcus aureus* outbreak in India ( Sudhakar, et. al.,1988) showed that 41% of the total cost of the outbreak was borne by the affected persons, including loss of wages or productivity and other expenses. On the basis of the percentage of per capita income, the economic burden on affected people in India was higher than in the case of a similar outbreak in USA.

*Food control systems.* Almost all countries have a food control system, however poorly developed, to protect their populations against unsafe, adulterated, or otherwise poor quality food, yet human beings world wide continue to be afflicted with unsafe food. The increasingly globalized nature of the food systems, implying extended food chains, over the years has contributed greatly to undesirable outcomes. . As larger quantities of food pass through a multitude of food handlers and middlemen over extended period of time through the food production, processing, storage and distribution chain, control has become difficult, increasing the risks of exposing food to contamination or adulteration. This is compounded by the fact that in many countries - particularly developing countries - existing food legislation is outdated, and in need of overall review. There is also weak policy compliance and inadequate infrastructure for enforcing food control systems in many settings.

*A focus on developing countries:* High levels of toxic residues, with food additives, pesticides, and antibiotics surpassing maximum residue levels (MRLs) escape the scrutiny of food quality controllers in domestic or international markets. While poverty is the underlying cause of consumption of unsafe food in developing countries, particularly Africa, other factors, such as lack of access to clean water, weak government structures, population growth, the rise of Acquired Immunodeficiency Syndrome (AIDS) and other communicable diseases, trade pressure, and poor environmental conditions exacerbate the situation. The abundance of national legislation and limited resources to control the quality of imported foodstuffs further compound the challenges. The lack of food safety education of producers and consumers is another issue (CSPI, 2005).

*2.3.3.1.3. - Principal sources and causes of food-borne illnesses*

The potential for food to become contaminated with chemical substances or microorganisms starts from the time it is harvested or in some cases from pre-harvest and continues right through until the time it is eaten. In general, the risks to food safety mainly fall into two broad categories, namely microbiological contamination and chemical contaminants. Whether a contaminant will pose a health hazard or not depends on many factors including the absorption and toxicity of the substance, the level of the contaminant present in the food, the amount of contaminated food that is consumed, the health of the consumer, and the duration of exposure. Individuals differ in their sensitivity to contaminants and other factors in the diet can have an impact on the contaminant's toxic consequences.

*Microbiological contaminants.* These include bacteria, fungi, viruses or parasites and usually results in acute symptoms.  The most reported causes of food-borne illnesses are of microbiological origin. Microbes can enter the food chain at any point from the agriculture producer to the consumer's kitchen. Quality assurance systems have been introduced  to minimize the risk of microbiological contamination. However, as most of our food is not sterile, if handled improperly contamination may occur.

Most countries with systems for reporting cases of food-borne illness have documented significant increases over the past few decades in the incidence of diseases caused by pathogenic microorganisms in food, including pathogens such as *Salmonella*, *Campylobacter jejuni* and enterohaemorrhagic *Escherichia coli*, and parasites such as *cryptosporidium, cryptospora,* trematodes. In Latin America, the most frequent bacterial agents involved were *Salmonella spp.* (20 percent of the reported outbreaks) (FAO/WHO, 2004), *Staphylococcus aureus*, and *Clostridium perfringens* (CSPI, 2005). Another pathogen, *Escherichia coli* O157:H7, has increased dramatically in the Central and South American Region. Argentina has one of the highest incidences of HUS -- a serious complication of *E. coli* infection -- especially in the pediatric age group (CSPI, 2005).

Food items most commonly associated with the reported outbreaks were: fish/seafood (22 %), water

(20 %) and red meats (14 %) (CSPI, 2005). Examples include a major *E. coli* O157:H7 outbreak in Japan linked to sprouts involving more than 9,000 cases in 1996, and several recent *Cyclospora* outbreaks associated with raspberries in North America and Canada, and lettuce in Germany (Bern et. al., 1999; Döller et.al,,2002; and Hodeshi et. al., 1999) . In 1994, an outbreak of salmonellosis due to contaminated ice cream occurred in the USA, affecting an estimated 224,000 persons. In 1988, an outbreak of hepatitis A, resulting from the consumption of contaminated clams, affected some 300,000 individuals in China (WHO, 2002).

Viruses are also a source of threat to food safety. In Finland, the most common cause of food and water-borne food poisonings is a noro-virus (EVIRA, 2006). A 1998 outbreak of Nipah virus typically associated with pigs and pork (WHO, 2004) killed 105 people in Malaysia. The parasitic disease trichinellosis is increasingly reported in the Balkan region among the non-Muslim population, owing in part to the consumption of pork products processed at home without adherence to mandatory veterinary controls.

INSERT TABLE 2.9 HERE

*Chemical contamination.* Chemicals are a significant source of food-borne illness, although effects are often difficult to link with a particular food as their effects are normally slow and go unnoticed until permanent or chronic damage occurs. Under this category are environmental chemicals including pesticide residues, veterinary drug residues, heavy metals or other residues intentionally, unintentionally or accidentally introduced into the food supply during farming, processing, shipping or packing. Few data are available on the toxicology of chemical contaminants in food, estimation of the exposure of specific subpopulations often being hampered by inadequate data on dietary intake and on levels of contamination in the food actually eaten. This lack of information is exacerbated in developing countries, where little reliable information is available on the exposure of their populations to chemicals in food. Accidental and intentional adulteration of food by toxic substances can result in serious public health incidents. Three examples illustrate the general point. During the winter of 1971-1972, wheat seeds intended for crop planting and treated with methylmercury were accidentally distributed in rural areas of Iraq. An estimated 50,000 people were exposed to the contaminated bread made from the wheat, of whom 6,530 were hospitalized and 459 died. (Documentation of the Iraq study, 1987,1989, 1995 ). In Spain in 1981-1982, contaminated rapeseed oil de-natured with aniline killed more than 2,000 people and caused disabling injuries to another 20,000 - many permanently. (CDCP, 1982). In China, in 2002, more than 200 school children sickened and 38 died when rat poison was used to intentionally contaminate bakery products. (CNN, 2002).

*Mycotoxin.* Mycotoxins are toxins produced by certain fungi or moulds that grow on foods such as peanuts, tree nuts, corn, cereals, soybeans, animal feeds, dried fruits and spices. The toxins may be produced as crops grow or develop later during poor storage or handling. Mycotoxins can also enter the food chain via meat or other animal products such as eggs, milk and cheese as the result of livestock eating contaminated feed. Careful surveillance procedures and proper storage conditions of foods are important in helping to prevent the development of mycotoxins. The chronic incidence of aflatoxin in diets is evident from the presence of aflatoxin M1 in human breast milk in Ghana, Nigeria, Sierra Leone, and Sudan and in umbilical cord blood samples in Ghana, Kenya, Nigeria, and Sierra Leone. Together with the hepatitis B virus, aflatoxins contribute to the high incidence of primary liver cancer in tropical Africa. Moreover, children exposed to aflatoxins may experience stunted growth or be chronically underweight and thus be more susceptible to infectious diseases in childhood and later life. (CSPI, 2005).

*Pesticides residues.* More than 800 pesticides are currently approved for use in Europe. The procedure for establishing if a new product merits registration is complex. It requires many toxicity and efficacy studies before initial field tests can be carried out. It also includes tests on the degradation of the product and its derivatives in the plant and in the environment.  However, the procedures, although continually reviewed, may lag behind evidence of harm. For instance, some  chemicals approved for use are similar in their action to mammalian hormones; they have been shown to interfere with endocrine systems and may be a risk factor for non-human species such as amphibians and for diseases like obesity, different forms of cancer and diabetes as well as for reduced fertility. Evidence for harmful impacts of pesticides on humans when standard operating procedures for handling and application are adhered are rare; however, the risk lies in part in the difficulties in ensuring that appropriate procedures are followed . The latest European monitoring of pesticide residues in food found 4.7% of all samples exceeding the legal threshold of pesticide residues in food and almost half of all samples had detectable levels of pesticide residues (EC, 2006). In developing countries also, pesticide residues are threatening consumer's health. For instance, Viet Nam reports a high burden of disease associated with pesticide residues (Nguyên and Dao, 2001).

*Antibiotics and growth promoters (hormones).*  The use of antibiotics and growth hormones in livestock has been a controversial matter for many years. The use of antibiotics in livestock farming is essential to help prevent the widespread and devastating effects of diseases in herds. In some cases, antibiotics have been added to feed to promote growth. Low residues of the drugs may build up in the fatty tissue, kidneys and liver of animals.  Although these levels are thought not to pose any risk to human health, they are suspected as one of the causes of the emergence of antibiotic-resistant species of bacteria in the human medical arena.  The U.S. Food and Drug Administration (U.S. FDA) estimates that 5,000 people per year have had illnesses prolonged due to the use of a medically important antibiotic (fluoroquinolone) in flocks of poultry.  In March 2002, the EU proposed that the use of antibiotics as growth-promoting agents should be phased out by 2006 (WHO,2002) and (Regulation [EC] No 1831/2003) and the EU banned the use of growth hormones in livestock in 1988  the practice still continues in the US, Canada and in Australia. The topic remains controversial especially in terms of the international trade of hormone-treated beef.

*Industrial and environmental chemical pollutants:*

a-Dioxins and Plychlorinated Biphenyles (PCBs)

Dioxins and polychlorinated biphenyls (PCBs) are toxic chemicals that belong to the class of persistent organic pollutants (POPs). They are by-products of certain industrial chemicals and incineration or burning. Dioxins and PCBs are environmental contaminants that persist in the environment for many years and can find their way onto and into foods. In fish, polluted water is the main cause of dioxin contamination while animals are mostly exposed to dioxins through the air. Dioxin concentrates in the fatty tissues of livestock and fish. More than 90% of human exposure occurs mainly through foodstuffs. Those of animal origin normally account for approximate 80% of the overall exposure. Despite point-source incidents (e.g. Belgium, 1999), available data shows that the background exposure to dioxin of the European population has decreased over the last 10 years. The overall goal of the current EU policy on dioxins is to reduce dioxin levels in products and hence human exposure by about 25% by 2006. Marked elevation of dioxins associated with the herbicide Agent Orange was recently found in 19 of 20 blood samples from persons living in Bien Hoa, a large city in southern Vietnam, who were exposed to the chemical during 1966-1970.(Schecter, et. al, year.) The unexpected finding of soil, sediment and human contamination with 2,3,7,8 tetrachlorodibenzo-p-dioxin (abbreviated as 2,3,7,8-TCDD) that was last applied 30 years ago suggests the existence of other dioxin-contaminated sites in Vietnam and elsewhere that may result in substantial environmental contamination and human harm decades later.

PCBs are fat-soluble, accumulating in the marine food chain and reaching high levels in predator fish. More than 90 percent of Americans' exposure results from diet, mostly from fish. Children also can be exposed through breast milk. Human fetuses are also exposed, as PCBs are able to cross the placenta and concentrate in the fatty tissue of the brain (FNBIM, 1991).

b-Heavy metals

Other industrial/environmental pollutants include heavy metals such as mercury, lead and cadmium. Fish are especially vulnerable to environmental pollutants because waters can become contaminated from industrial discharges or accidental spillage. The EU has standards for mercury and other heavy metal contaminants in foods and the levels are routinely monitored. Mercury tends to bio-accumulate in large ocean-dwelling fish. That has caused several European countries to recommend that vulnerable groups, including pregnant women, limit their intake of certain fish known to contain high levels of mercury. In the United States, scientists at the U.S. Environmental Protection Agency (U.S. EPA) have estimated that as many as 630,000 children are born each year having been exposed to unsafe levels of mercury in the womb. Many adverse birth outcomes have been linked to prenatal exposure to excessive amounts of mercury. Even small amounts are predicted to cause delayed motor development, delayed speech, and other adverse effects among exposed children (FNBIM, 1991 ).

*Acrylamide.* Acrylamide is formed during the frying, roasting, or baking of a variety of foods, including potatoes, cereal products and coffee, generally at temperatures above 120 °C.(INFOSAN, 2005). Concern about acrylamide as a cooking carcinogen was raised first by Swedish scientists (Tareke et.

al., 2000), followed by several scientific studies in other countries also. They reported data that renders it likely that acrylamide - formed when certain foods, particularly plant-based foods that are rich in carbohydrates and low in protein, are cooked at high temperatures such as in frying, roasting or baking - is a major source of the background dose of AA also in humans. An evaluation of cancer tests of AA and available data on its metabolism in the human body leads to the estimation that the background dose of AA is associated with a considerable cancer risk. An FAO/WHO Acrylamide in Food Network (Acrylamide Infonet, operated by the Joint Institute for Food Safety and Applied Nutrition, JIFSAN) was established as a result of the June 2002 FAO/WHO Consultation on the health Risks of Acrylamide in Food, to function as a global resource and inventory of ongoing research on acrylamide in food .

*Radiation.* Food irradiation is a process in which food is treated with a controlled amount of ionizing radiation to kill or control bacteria, parasites, insects, and fungi. Irradiation is also used to reduce spoilage and slow down ripening and sprouting of produce (CDC, 2005). There has been controversy particularly in the North American region over the risks and benefits of irradiation. In certain situations, irradiation may be useful to reduce the risk of microbial food-borne illness. Some consumer groups believe that irradiation may cause other problems. Among their concerns are inadequate testing and approval processes, dangers to workers and the environment, toxic byproducts, and the potential for cellular or genetic damage. Scientific and medical groups, industry, and government contend that irradiation is safe and a useful way to reduce the risk posed by harmful bacteria in the food supply. All irradiated foods must be labeled. In addition to a written description, such as “irradiated,” a distinctive logo - the “radura” - must be on the package to identify the product. The European Commission heavily regulates irradiated foods and food ingredients (Directive 1999/2/EC). A variety of foods have been approved for irradiation in the United States, for several different purposes. U.S. consumers have been wary of irradiated food – they feel, for good reason. The technology does not just kill bacteria; it depletes vitamins and creates new chemicals in foods that affect taste and smell. Studies have shown that irradiation destroys vitamin A, beta-carotene, and vitamin C in potatoes, orange juice and other foods (OCA, 2006).

*2.3.3.1.4. Major institutional arrangements*

*Codex Alimentarius Commission.* The Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Program. The main purposes of this program are protecting the health of the consumers and ensuring fair trade practices in the food trade, and promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations. Codex provisions concern the hygienic and nutritional quality of food, including microbiological norms, food additives, pesticide and veterinary drug residues, contaminants, labelling and presentation, and methods of sampling and risk analysis.

In December 2002 FAO and WHO completed an evaluation of the Codex Alimentarius. The evaluation found Codex food standards to be given very high importance by members. Codex standards were considered a vital component in promoting food control systems designed to protect consumer health, including issues related to international trade and the agreements on the Application of Sanitary and Phytosanitary Measures (SPS) and on Technical Barriers to Trade (TBT) of the World Trade Organization (WTO). The evaluation concluded that international standards also provide a basis for standard setting by smaller and less developed countries. However, the evaluation also showed that developing countries feel unable to participate as effectively as they would wish in the Codex negotiations. It was found that 96 % of low-income countries and 87% of middle-income countries do not participate in the Codex to the extent they think desirable. There is some concern also among developing countries that their priorities are not always reflected in the standards developed by Codex, so Codex is not as useful as it might be in protecting their interests. Developed countries in particular are concerned that the food standards program is too slow and that the usefulness of Codex standards would be greater if standards were produced in a timelier manner. Finally it may be noted that the evaluation produced wide agreement that science-based prioritization of health issues for standard setting was a priority and that a strengthened risk assessment procedure was necessary as an input into the formulation of Codex standards.

(Codexhttp://www.codexalimentarius.net/web/evaluation_en.jsp).

*The European Food Safety Authority (EFSA).* Following a series of food scares in the 1990s (e.g., BSE, dioxins…) which undermined consumer confidence in the safety of the food chain, the European Union concluded that it needed to establish a new scientific body charged with providing independent and objective advice on food safety issues associated with the food chain. The result was the European Food Safety Authority (EFSA). EFSA's risk assessments are carried out by its Scientific Committee and eight Scientific Panels covering specialized thematic areas such as food additives, flavorings, processing aids and materials in contact with food (AFC); additives and products or substances used in animal feed (FEEDAP); plant health, plant protection products and their residues (PPR); genetically modified organisms (GMO); dietetic products, nutrition and allergies (NDA); biological hazards, contaminants in the food chain (CONTAM); animal health and welfare (AHAW).

*US Food and Drug Administration (FDA) and the FQPA 1996:* The Food and Drug Administration celebrated its 100th anniversary in 2006. The Center for Food Safety and Applied Nutrition (CFSAN), in conjunction with the FDA's field staff, is responsible for promoting and protecting the public's health by ensuring that the nation's food supply is safe, sanitary, wholesome, and honestly labeled. Some of CFSAN's current areas of food safety concern are: biological pathogens, naturally occurring toxins, dietary supplements (e.g., ephedra), pesticide residues, toxic metals, decomposition and filth (e.g., insect fragments) and food allergens (e.g., eggs, peanuts, wheat, and milk). Others are, nutrient concerns (e.g., vitamin D overdose, pediatric iron toxicity), dietary components (e.g., fat, cholesterol), radionuclides, TSE-type diseases (e.g., chronic wasting disease in elk); and product tampering.

INSERT BOX 2.15 HERE

*2.3.3.1.5. Risk and crisis*

Risk can be defined in general as the probability or probability distribution of an event, or the product of the magnitude of an event and the probability of its occurrence. Concerns about the risks related to food production and consumption are not a recent phenomenon. The development of agro-food systems over the last sixty years has been paralleled by sustained efforts to reduce risks and sustain trust among the many actors involved in food regimes. However, both the definition of food risks and the institutions and discourses used to dispel anxiety and build trust have been far from stable throughout this period. In the contemporary world-order, food risks and the practices and institutions dealing with these risks reflect the significant transformations that have taken place in agro-food systems, the changing nature of the risks involved in food production and consumption, and modifications in scientific risk assessment and risk management (Mol & Bulkeley, 2002). Conventional risks related to microorganisms, food-poisoning, additives and agrichemicals, still exist and continue to attract attention. But a new category of risks has emerged, of which BSE, genetically modified organisms (GMOs), and zootic diseases such as avian flu, are among the most prominent. The routes through which these risks may affect nature and society are more complex, less 'visible' and less detectable than 'conventional' risks, and are often highly dissociated over space and time (Mol & Bulkeley, 2002).

*Bovine spongiform encephalopathy (BSE).* The most important food scare in recent times remains the Bovine Spongiform Encephalopathy (BSE) crisis; a notable feature of he crisis is the way that emphasis shifted from the management of thebeef industry to health concerns and the impacts on rural economies of the measures mounted in response. This crisis, and especially the response that was made to it, caused demonstrable and severe loss of public confidence in food, especially beef, and more broadly in industrialized farm production systems (Latouche et. al.,1998).

<u>The disease</u>. Bovine Spongiform Encephalopathy (BSE), commonly known as "mad cow disease", is a fatal brain disease that affects cattle. It is thought that cattle may have become infected with BSE by feeding them with meal or animal feed produced from BSE-infected carcasses of dead or slaughtered animals. Other possible routes and causes of transmission are yet to be ruled out. Although no causal link has been formally established between ingestion of BSE-infected material and vCJD, only those who have eaten BSE-infected "specified risk material" (SRM) are thought to be at risk from vCJD. SRM refers to the parts of cattle that are most likely to be infected with the BSE agent and include the central nervous system including the brain, the spinal cord, the eye and part of the large intestine. The BSE agent has not been detected in muscle meat (beef) or milk and WHO and EU experts regard bovine milk and muscle meat to be safe.

<u>The crisis.</u> BSE was first diagnosed in cattle in the United Kingdom (UK) in 1986 and has been in decline since 1992. Meanwhile it has spread to other countries throughout Europe; single cases also have been detected in the USA and Canada. Fewer than 150 people, globally, have been diagnosed

with variant Creutzfeldt–Jakob disease (vCJD), but there are many uncertainties about the future course of the epidemic because of the long and variable incubation period (5 years). Better control measures are thought necessary to guard against the possibility of iatrogenic transmission through blood transfusion or contaminated surgical instruments. These measures will require sensitive and specific diagnostic tests and improved decontamination methods (Smith, 2003).

*Biotechnology (genetic modification).* Genetically altered crops are slipping into the food chain; foreign countries are placing restrictions on imports; farmers in rural America are panicking. One of the first food crops to be modified, maize, caused similar concern when it was brought into mass production. Today, America's rice-farmers are facing a similar drama (The Economist, 2006). The evidence since the introduction of GM maize is that contamination of non-GM crops with the kinds of GM constructs used so far cannot be prevented once they are brought into broad-scale production. The speed and scale of pollen flows, often over long distances, is better understood as well as the risks of direct seed transfer caused by seed carryover to the following year’s crops, natural occurrences (wind, flood etc), animal transfer, machinery and human error (Network of Concerned Farmers, 2004). However, there is no consensus so far as to whether this contamination matters to people’s health, other species, and the environment, and if so, to what degree.

The Quality and Standards Service unit of the FAO has stated that (GM) foods can harm consumers if the modification transfers allergens from one organism to another. For example, someone allergic to groundnuts might react to a completely different food into which the groundnut-allergen has been transferred. The FAO therefore recommends that regulations should require that food labeling specifies any GM ingredients that transmit commonly known allergens (www.fao.org/WorldFoodSummit/english/fsheets/fsafety.pdf. See 2.3.1. for more details).

*2.3.3.1.6. Trends and emergent stakes*

The value of the world food trade in 1997 was about $ 458 billion, and is increasing every year (WTO 1998). In spite of significant progress in medicine, food science and the technology of production of food, outbreaks of food-borne illness stubbornly continue to increase. In recent years there has been a number of extremely serious outbreaks in virtually every continent.

*Elements that fuel food safety concerns.* The reasons suggested for the increase in outbreaks are many and varied. They include: better reporting, the globalization of food trade (implying that food can become contaminated in one country and infect people in another), increasing urbanization and dependence on stored food. In addition the intensification of food production and consolidation of food industries present opportunities for contaminated products to affect large numbers of people.

New diseases. A further complicating factor has been the emergence in recent years of pathogenic bacteria, such as *Listeria monocytogenes* and *Escherichia coli* 0157:H7, capable of causing very serious illness in susceptible people. Consumer confidence in the food industry, and government's ability to regulate it, has been weakened by the outbreaks and their own experiences, compounded by further revelations of feed contamination with dioxins. Serious fish safety problems in developing countries are poorly quantified, such as those involving parasites and natural toxins.

Complex chains. Food supply systems in developing countries are often fragmented involving a multitude of middlemen. This exposes it to various types of fraudulent practices. These may include simple adulteration of food with something of lesser value or no value at all, or mislabeling the product with the intent of misleading the consumer. Besides the public health impact due to the reduction in the nutrient content of food or food contamination, the consumer is defrauded. Considering that in developing countries, people spend almost 50% of their earnings on food, and among lower-income households this figure may rise to above 70%, the impact of such fraudulent practices can be quite devastating (Malik, 1981).

*Risks / controversies/challenges.* However, scientific developments have allowed a better understanding of the nutritional qualities of foods and their health implications. These trends have also led consumers to become more discriminating in food matters and to demand protection from inferior quality and unsafe foods. Nevertheless, numerous controversies are still to be addressed. In the conclusion of an international workshop on the subject, Hanak et al. noted a number of challenges that food safety management will have to address in the coming future ;

- poor people are buying cheap food, whether it is safe or not. Thus arise a question about food safety being a public good under the responsibility of the society as a whole or being an individual choice enacted on a market with different levels of safety determined by price;
- as it is the case in developing countries, export safety standards are often higher than those applied to products on domestic markets. This raises a policy question about the ways (training, incentives, …) to favor a positive spill-over from one sector to the other
- HACCP has developed tremendously fast but this success poses key questions about its cost-effectiveness in developed countries (Unnevehr and Jensen, 1999).It is scale-sensitive, prone to be limited in use to large scale firms, and is likely to create numerous problems in developing countries (Farina, Reardon, 2000).
- In shifting the burden of standards from end-products to the whole process, government unloads its primary responsibility for safety to the private sector and becomes simply the auditor of the industry's programs. or in developing countries. There is an increasing pressure for wider public involvement to help local industries build their "quality assurance" processes, to inform or train consumers and their organizations, monitor food-borne illnesses and epidemiological researches, and in proactive representation in international institutional arrangements.
- Food safety asks for a growing involvement of science (identification and characterization of hazards, assessment of a population's exposure, characterization of the risk, for whom). Under pressure of public fears, science is required to deliver rapid answers. Under pressure of commercial interests, science is caught in trade disputes wherein risk assessment methods are controversial. Moreover, science is asked to deal with probable risk when evidence is inconclusive,

which raises the question of the relevant use of the "precautionary principle".

- As a result of the failure to control food-borne disease and of an increased knowledge among consumers, both the food industry and government regulators are feeling the backlash of consumer mistrust, which is reflected in growing consumer activism. Consumers are increasingly becoming involved in the process of regulation and are no longer just a part of the market place, accepting or rejecting products on the grounds of price or quality.

*Emergent stakes*

a) Environmental issue

Food is a good indicator of the state of the environment in which it is produced. Monitoring of environmental contaminants in food therefore not only assists in ensuring food safety but can also give early warnings about the state of the environment, such as level of heavy metal contamination, thereby catalyzing appropriate action to maintain food and ecosystem health.

b) Stakes for developing countries

Access by developing countries to food export markets in general, and of the industrialized world in particular, will depend on their capacity to meet the regulatory requirements of importing countries. For most developing countries, agriculture lies at the center of their economies and food exports are a major source of foreign exchange and income generation for rural and urban workers in agriculture and agro-industrial sectors. The long-term solution for developing countries to sustain a demand for their products in regional and world markets lies in building up the trust and confidence of importers in the quality and safety of their food supply systems. This will require a significant improvement within national food control systems and within industry food quality and safety programs. Such efforts will greatly help in increasing the relatively small share of developing countries in regional and international food trade.

*2.3.3.1.6. Overall assessment*

Food-borne illnesses represent a major and daily health threat in all countries, from the most to the least industrialized. Recent trends in global food production, processing, distribution, and preparation are creating a growing demand by consumers for effective, coordinated, and proactive national food safety systems. Those programs are essential to protect consumers and environmental health and protect national economies from trade disruptions. The evidence of the last sixty years is that food safety programs can support IAASTD goals by covering the entire food chain from production to consumption; taking into account both naturally occurring, and deliberate threats of contamination; considering national, regional, and international specificities and requirements; involving consumers and becoming transparent.

Governments continue to play critical roles in protecting the food supply. However, governments in many countries are poorly equipped to respond to the growing dominance of the food industry and to existing and emerging food safety problems. They lack technical and financial resources, effective institutional frameworks, trained personnel, and sufficient information about the hazards and risks involved. To improve food safety and enable their industries to participate competitively in food markets, governments should have up-to-date food legislation and regulations that address global concerns, as well as specific national and regional needs; inspection and food surveillance programs to inform and enforce legislation and regulations; increase health surveillance to ensure the availability of reliable data on which to base risk-management decisions provide for regulatory oversight that extends from farm to table promote systems of preventative controls within the food industry, such as the Hazard Analysis and Critical Control Point System (HACCP); undertake intensive efforts to educate the food industry, food-handlers, and consumers; place food safety on the political agenda as a priority in public health, and as a first step toward reducing food-borne illness.

In all the above, it is critical to develop the support and coordination of all concerned partners: national agencies, international organizations, health and education sectors, industries, farmers, and consumer groups. By sharing their national experiences and knowledge, consumer groups in particular can participate vigorously in policy debates and reduce the serious adverse effects of food-borne diseases worldwide (CSPI), 2005). It is also clear that food safety decisions need to be free from capture by political or industry interests. Although there is no consensus the “precautionary principle” to regulate food safety might be justified in terms of food safety. There is growing pressure for governments once more to play a lead role in putting public good interests first and safeguards in place in the face of rapid changes in the organization of food systems (Mol and Bulkeley, 2002)

2.3.3.2. Food Security and food sovereignty

*2.3.3.2.1.Food production, food supply and nutritional status trends*

Before the middle of the nineteenth century “hunger and premature death” was the norm for most of humanity. During the 1950s, this phenomenon was only common in the developing world, with life expectancy hovering around 40 years and hunger, stunting, nutritional deficiencies and diseases widespread (Fogel, 2004). Things changed around the middle of the 20th century. By then, many poorer countries’ average food consumption had increased by 20%, real prices of food had fallen despite a doubling of population and life expectancy had increased from 40 to 64 years (FAO, 2002).

The weight of the evidence is that the growth of the productive potential of global agriculture has so far been more than sufficient to meet the growth of effective demand, although the global food situation displays acute structural imbalances (Mellor, 1999; Stringer 2000). According to Paarlberg (2002), per capita food production in developing countries increased by 51% between 1970 and 2000, particularly in the Asian region, where the growth was as high as 75%, but Africa lagged behind, growing only by on 9%. This growth resulted in a considerable progress, especially over the last four decades, in raising the average world food consumption (kcal/person/day) (Garett, 1997; Izquierdo and de la Silva 2000; Stringer, 2000), a variable that closely correlates with the incidence of undernourishment. The world average kcal/person/day has grown by 19 percent from the mid-1960s to 2 800 kcal. This gain reflects predominantly those developing countries where the average grew by more than 70%, notably in China and Indonesia; the average grew more than 50% in Pakistan and Korea; and more than 30%

in Brazil, Burkina Faso, the Dominican Republic, Ecuador, El Salvador, Jamaica, Mauritania and the Philippines. Industrial countries and the transition economies had already reached fairly high levels of per capita consumption by the mid1960s. In Sub-Saharan Africa, however, food consumption per capita has been static (Fig 2.13) or even declining in some countries compared to the early 1960s (Wafula and Ndiritu 1996).

INSERT FIG. 2.13 HERE

Stringer (2000) notes that the increases in agricultural productivity recorded during the last few decades has halted or even begun to reverse in the regions such as Asia where the green revolution played a strong role in increasing agricultural productivity in the 1970/80s (see previous subchapters ). For example in Indonesia rice yields have declined from 5.2 in the 1970/80s to 3% in the late 1990s; and in China, from 4% a year in the 1970s to 1.6% in the1980s. Wiggins (2000) and Paarlberg (2002) also point out that Africa has the lowest production per unit area of land in the world. For example, the average production of sweet potato is estimated to be 6 tones per hectare compared to the global average of 14 tones per hectare. China produces an average of 18 tones per hectare, which is three times the African average. The average maize yield in Africa was about 1.7 tons per hectare during the 1990s compared to a global average of 4 tons per hectare. Africa has been a perpetual food importer with a negative staple food trade ever since the early sixties (Table 2; FAO, 2004).

The pattern of the food supply imbalances is reflected in the incidence of under-nutrition. According to FAO data (FAO, 2001a) 815 million people were under-nourished in 1990/92 (20 percent of the global population), decreasing to 777 million people in 1997/99 (17 percent of the global population). Of these, 27 million were from transition countries and 11 million in the developed market economies; Africa accounted for about a quarter (24%) of the global undernourished population. Chronic food shortages, as manifested in protein-energy malnutrition, over the same period fell in much of Asia and Latin America; in Sub-Saharan Africa the number of chronically food short people has increased since the 1960s (Fig 2.14). This trend is mirrored by the increasing proportion in SSA of those with prolonged deficits in energy intake (Fig. 2.15).

INSERT FIGs. 2.14 and 2.15

Ten years after the 1996 Rome World Food Summit (WFS), the number of undernourished people in the world remains stubbornly high. In 2001–03, FAO estimates there were still 854 million undernourished people worldwide: 820 million in the developing countries, 25 million in the transition countries and 9 million in the industrialized countries. Since then, virtually no progress has been made towards the WFS target of halving the number of undernourished people by 2015. Since 1990–92, the baseline period for the WFS target, the undernourished population in the developing countries has declined by only 3 million people: from 823 million to 820 million. This contrasts starkly with the reduction of 37 million achieved in the 1970s and of 100 million in the 1980s. Moreover, the most recent trends are a cause for concern – a decline of 26 million between 1990–92 and 1995–97 was followed by an increase of 23 million up to 2001–03. Because of population growth, the very small decrease in the number of hungry people has nevertheless resulted in a reduction in the proportion of undernourished people in the developing countries by 3 percentage points – from 20% in 1990–92 to 17% in 2001–03. This means that some progress has been made towards the first Millennium Development Goal of halving the percentage of undernourished people by 2015. However, progress over this period was slower than over the previous two decades, when the prevalence of undernourishment declined by 9%, from 37 to 28%) between 1969–71 and 1979–81 and by a further 8 percentage points (to 20%) between 1979–81 and 1990–92 (FAO, report on food insecurity in the world, 2006).

INSERT FIG. 2.16

*2.3.3.2.2. Food security*

Definitions. The term food security originated in the international development literature in the 1960s and 1970s (FAO, 1983a; Ayalew, 1997, Stringer, 2000; Windfuhr and Jonsén, 2005; Ganapath et al, 2005). Public interest in global and domestic food security grew rapidly following the oil crisis and related food crisis of 1972-74 (Saad 1999; Stringer, 2000; Clover 2003), the African famine of 1984-85. One of the first responses was the establishment of growing numbers of food banks .

At least 200 definitions and 450 indicators of food security are noted in the literature (Ganapath et al. 2005). Early definitions of food security focused on aggregate food supplies at national and global levels, and analysts advocated production for self-sufficiency as a strategy for nations to achieve food security (Clover 2003). The 1974 World Food Conference defined food security as: “availability at all times of adequate world supplies of basic food-stuffs” (United Nations, 1975; Clover 2003). A paradigm shift emerged during a seminar on Poverty and Famines that demonstrated the importance of defining food security in terms of access to food by individuals, in addition to aggregate food availability. The data presented also highlighted the importance of maintaining the entitlements of individuals and groups to access food in times of food scarcity (Sen, 1981). The commonly accepted definition of food security was broadened to “Ensuring that all people at all times have both physical and economic access to the basic food they need” (Ganapath et al. 2005).

In the mid 1980’s two more parameters were recognized. (1) distinguishing between household and individuals in analysis, noting that access to food is linked to an individual’s control over or access to household resources; and (2) paying attention to both supply-side and demand side variables as well as to variations in individual nutritional requirements based on age, job, physical activities, size and health (Stringer, 2000). This led to a further re-definition of food security, proposed by the World Bank, broadening the emphasis to include access to food, but narrowing the focus from the global and national to households and individuals: “secure access by all people at all times to enough food for an active, healthy life” (WFC, 1983; FAO, 1983c; World Bank, 1986). In the 1990s the food security literature expanded to encompass market growth, agricultural development, poverty reduction, demographic trends, raising incomes, changing consumption patterns, gender issues and the environment (Stringer, 2000; Ganapath et al. 2005). Currently, widely accepted definitions take on board acceptability; nutritional adequacy; safety in addition to availability and assured access (Saad, 1999; IDRC, 1999).

INSERT FIG. 2.17 HERE

Historical overview. Food security was elevated to become a global policy concern at the 1974 World Food Conference, held at a time when world food supplies were tight and large-scale food shortages and starvation appeared imminent. In response to the perceived crisis, such bodies as the World Food Council, the FAO Committee on World Food Security and the Committee on Food Aid Policies and Programs were formed. Their activities focused on increasing domestic agricultural production and creating international grain reserves. Reviews by Stringer (2000) and Windfuhr and Jonsén, (2005) indicate that during this period the definition of food security which was in use was based primarily on the collective ability of nations and the world to produce enough food, particularly cereals (Stringer, 2000) for the expanding population. The achievement of national self-sufficiency was seen as a necessary strategic goal. Food security was measured in terms of commercial food prices and physical food availability, rather than by the effective demand and consumption of poor people or nutritionally vulnerable groups. Especially under specific political regimes, this kind of narrow approach drove countries toward autarkic policies, sometimes with terrible results, such as the famines in China (after the Great Leap Forward) or more recently in North Korea.

By the early 1980s many of the assumptions underlying the 1974 conference had proven to be unfounded. It was recognized that increased food production was a necessary but not sufficient or simple answer to the hunger problem.. The distributional aspects of food security came more to the fore. The 'FAO Plan of Action for World Food Security' adopted in 1979 by the Conference of the FAO, therefore introduced the term "national food security" to describe ways of achieving a better national distribution of food. Within the framework of 'national food security' policies, aspects such as grain reserves, import and export quotas, food aid, agricultural techniques to increase production, and irrigation were discussed. Trade flows, labor and transfers were recognized as important creators of access to and distributors of food (Sen, 1981, quoted in Stevens et al…2005). Food security became seen as a twofold responsibility, a state affair and a phenomenon related to individuals.

The complex determinants of food security. Fig .2.18 presents a contemporary conceptual framework for understanding food security, adopted from Webb & Rogers (2003). It shows interacting factors and conditions necessary to guarantee availability, access and utilization to ensure positive food security. However, it emphasizes that it is necessary to focus on agriculture and trade as the two major elements of national policies, that are heavily determinant of the nutritional status of a given country.

INSERT FIG 2.18 HERE

*Agriculture and rural development.* In assessing the data relevant to issues of food insecurity, agriculture emerges as relatively far more important in the countries where hunger is widespread. “Today, 75% of poor people live in rural areas and increases in urban poverty tend to be fuelled by people migrating to the cities to escape rural deprivation “ (FAO 2003). This suggests that “no sustained reduction in hunger is possible without special emphasis on agricultural and rural development” (FAO 2006). Yet the share of agricultural output in total production in developing countries as a group has declined from 26% in the early 1960s to 13% in 1997. For the same period, agriculture’s share of GDP fell from 40-18% in East Asia; 43-25% in South Asia; 17-8% in Latin America and the Caribbean and 28-18% in Sub-Saharan Africa

INSERT FIG. 2.19 HERE

The chronic food insecurity in sub-Saharan Africa may be attributed to, among other reasons, chronic civil wars; social strife; climatic changes (alternative droughts and floods); long term consequences of cold war era on agriculture and rural development polices, and overall mismanagement of natural resources (Badiane and Delgado, 1995), structural adjustment policies that were imposed in many developing countries in the late 1970/80s; world agricultural trade policies, as well as agricultural subsidies in developed countries (Chopra, 2004; see further below).

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INSERT FIG. 2.20 HERE

These trends could seem paradoxical inasmuch as national food security relies in a significant way on agricultural production. However, at the individual level, poor people face many constraints to the development of production; not least, they must have access to productive assets such as land, water, livestock, plantations, etc. on the basis of stabilized rights. The matter of rights is an important domain wherein policies can strengthen the production-based “entitlement” (Sen, 1981) of poor people, of women, of minority groups, or landless farmers.

A growing constraint to food security is the HIV and AIDS pandemic which threatens directly rural people’s well-being, productive capacity, and the potential for agricultural and rural development. Today, 95% of people living with - and dying of - HIV and AIDS are in developing countries. The overwhelming majority are rural poor people, and among them women figure disproportionately. The epidemic is undoing decades of economic and social development and, where it is most prevalent, it is threatening the social cohesion of families and rural communities as well as increasing the burden of care at all levels, while weakening the productive capacity and food security of present and future generations (FAO, http://www.fao.org/hivaids/).

People may continue to rely on agricultural production to feed themselves and generate an income if other sources of food security are more difficult to tap. If agricultural prices are so low (relative to food prices on the market) that it is better to go and work temporarily outside the individual production unit, then trade and the sale of labor become the major sources of food security. Food prices are determined in part by regional and global food supplies (defined as national production plus imports through trade or aid), by access facilities (differences between regional infrastructures may translate into different prices; oil prices may affect transport prices and weigh heavily on remote areas), and government price policies. Many governments have found it difficult to coordinate policies across these policy sectors effectively, resulting in turbulence at local levels in market-mediated food security. The recent worldwide enthusiasm for the conversion of food crops to supply energy and fuel may complicate further the management of food security in the interests of the poor and most vulnerable; while some farmers and agro-industries gain, poor consumers (as in Mexico City) may experience steep rises in the price of their basic foodstuffs.

Agricultural employment (generating labor-based entitlements) has become an increasingly be important source of income, ever since the Green Revolution began to increase cropping intensities. Here again, the regulatory framework in the matter of labor laws, has been shown to playa major direct role (for instance, by setting minimum wages and labor conditions). By influencing the prices of commodities and by fostering export activities through ad hoc regulation, government policies may also foster the creation of employment opportunities and attractive income for poor households. Thereby the different determinants for food security in rural poor areas become importantly connected to the international flows that connect a country to the rest of the world's food security.

*Trade and aid.* Production and consumption of farm products are expanding faster in developing countries than in developed economies. However, productivity growth in the poorest nations is not keeping pace with the food needs of their rising populations. Because of this, the poorest developing countries are becoming increasingly dependent on world markets for their food security and so more vulnerable to international price fluctuations, according to the OECD-FAO Agricultural Outlook 2006-2015.Even where trade policy is only one factor amongst others which affects food security, its impact on individual and national "entitlements" (via production, trade, labor and transfers) is multifold since it weighs, positively and negatively, directly and indirectly, on prices, on the level of domestic and export production and the availability of labor for this production.

Food aid flows are a fourth determinant of food security. Transfer-based entitlements are different to the others in the sense that they are given by a third party. At the individual level, the impact of food aid on food security relies on the social capital of household members and is often informally implemented through gifts or loans from relatives or friends. At the national level, governments have received food aid under three main modalities; food aid programs (transfer of food commodities, to be used as balance of payments), project-based food aid (targeted to food insecure beneficiaries), and emergency food aid (distributed in times of acute food stress). Although there is a general agreement that emergency food aid flows are effective in sustaining entitlements to food during crisis (and may have positive income spillovers to others if the food distributed is bought on local or regional markets),, there is a greater concern about the shipment of big amounts of food at concessional prices under the two other modalities. These modalities often have had a “devastating effect on rural people whose livelihoods depend on the production and sale of staple crops” (Clark, 2001).

*Overall assessment of food security policies.* Based on the four categories of entitlements to food security elaborated by Sen, Stevens and al. proposed a range of policies that have been shown to support food security (see table 2.10). They stress the fact that far too often, impacts of change in trade policies have been analyzed at the macro-level, based on aggregated data, thus flattening down any differences between vulnerable and insecure groups and others. They raise methodological questions about the dialogue between macro and micro analysts and about data collection, challenging experts to operationalize new categories such as “food economy zones” in data collection and policy implementation.

INSERT TABLE 2.10 HERE

*2.3.3.2. 3. Food Sovereignty*

<u>Definition.</u> There is no universally agreed definition for the term ‘Food Sovereignty’ (Windfuhr and Jonsén, 2005)., A more widely accepted definition (People’s Food Sovereignty Network, 2002; http://en.wikipdia.org/wiki/Food_sovereignth#endnote_1996; www.foodsovereignty.org; FOEI, 2003; Chopra, 2004) states that:

“Food Sovereignty is the right of peoples to define their own food and agriculture; to protect and regulate domestic agricultural production and trade in order to achieve sustainable development objectives; to determine the extent to which they want to be self reliant; to restrict the dumping of products in their markets; and to provide local fisheries- based communities the priority in managing the use of and the rights to aquatic resources. Food Sovereignty does not negate trade, but rather it promotes the formulation of trade policies and practices that serve the rights of peoples to food and to safe, healthy and ecologically sustainable production”.

<u>Changing perspectives.</u> A chronological overview of food sovereignty is given by Menezes (2001) and Windfuhr and Jonsén (2005). They attribute the development of the concept to a global network of NGOs, CSOs and social movements, meeting at successive conferences and forums.. According to Windfuhr and Jonsén, (2005), Via Campesina, a global farmers’ movement, was using the concept already in the early 1990s, with the objective of encouraging NGOs and CSOs to discuss and promote alternatives to neo-liberal policies for achieving food security. The concept of Food Sovereignty became known worldwide as a result of the International Conference of the Via Campesina in Tlaxcala, Mexico, in April 1996. At the World Food Summit in 1996, Via Campesina launched to the general public a set of principles that offer an alternative to world trade policies and that would realize the human right to food (Menezes 2001; Windfuhr and Jonsén 2005).

INSERT BOX 2.16 HERE

In August the same year, reacting against the Mexican government's decision to increase maize imports from North America under the Free Trade Agreement (NAFTA), a large number of Mexican organizations and social movements organized the Foro Nacional por la Soberania Alimentaria in Mexico City. They underscored a perceived need to preserve the nation's autonomy in defining its food policy (Menezes 2001). Since then, an ever-growing number of NGOs, CSOs and social movements have adopted the Food Sovereignty principles and have sought to bring them into reality (Menezes, 2001; Windfuhr and Jonsén, 2005).

INSERT TABLE 2.11 HERE

Other players who have made a significant contribution are the collective efforts summarized in Table 1. Food Sovereignty has been proposed as a negotiating item under the Uruguay Round of Trade Negotiations (FOEI, 2001). It has been linked to wider movements of self-determination and endogenous development, exemplified for example by the establishment by the Quechua community of a Potato Park, near Cuzco in Peru (Argumedo and Pimbert, 2005) and the re-vitalisation of barter markets (www.diversefoodsystems.org), and by the establishment of a "Peasant World University" by Nayakrishi Andolan, a peasant movement in Bangladesh (http://membres.lycos.fr/ubinig/about2.htm).

Insert Table 1 here

Food Sovereignty and Food Security. The diverse perspectives that have evolved over the years on food systems, and the policies associated with them, have been pushed by the food sovereignty movement to recognize the issues of power that are signaled by discussion of 'rights'. By the assertion of the rights of smallholder farmers and communities in developing countries to produce food to meet their needs in harmony with food cultures (Figure 2) and cultural identities (Menezes 2001), a link has been made with those in industrial countries who are seeking alternatives to the increasing industrialisation of food production and food cultures and the dominance of corporate interests in food production and food retailing (Riches 1997; http://en.wikipedia.org; Rosset, 1996). This in turn has highlighted the increasingly numerous civil society actions across the world that seek a democratization of decision-making in agricultural, food and science policy-making processes, and that are building a resistance to the narrowing of the rights of citizenship to those of consumption.

Right to Food and Food Sovereignty. Market-oriented globalization of economic activity is an important driver of change in the evolution of agricultural trade and food systems. The development of the right to food based on normative qualities, is another driver, but with markedly different characteristics. The efforts made over the last fifty years to express in international and national laws a series of universal rights, including the right to food, has been an explicitly moral enterprise that stands in contrast to the economic processes of market-driven globalization. The right to food was included in the Universal Declaration of Human Rights adopted by the United Nations in 1948, following Franklin D. Roosevelt's speech in 1941 that captured the world proclaimed freedom from want and fear; freedom of speech and faith (Oshaug et al, 1994). The UN Declaration on the Right to Development Act 2 (UN, 1986) General Assembly Resolution 41/128, New York) states that 'the human being, being central subject to development, should be the active participant and beneficiary of the right to development'. The various human rights instruments brought into force have created expectations and obligations for the behavior of individuals, social groups, and States (Oshaug & Edie, 2003). People are expected to be responsible for satisfying their needs, using their own resources individually or in association with others. States are expected to respect and protect the freedom of the people to make these efforts and the sovereignty over the natural resources around them as well as obliged to fulfill everyone's enjoyment of the right to food and nutritional security. Successive efforts have been made to build such rights, expectations, and obligations into national laws and governance institutions providing developmental assistance. Norway has formulated food security and the right to food as the basis of its agricultural policy, strongly driven by consumer's needs. Brazil on the other hand has extended the concept of cultural heritage under Article 215 of its Constitution, to include food cultures. These efforts have had an explicitly normative quality. The technical standards expressed in international treaty instruments for food supply and nutritional adequacy, safety; cultural acceptability, supply stability. Economic, social and environmental sustainability have been developed in processes of negotiation and intensive discussions that reflect contrasting political priorities and ideologies (Oshaug, 2005). Adequacy of care for the most vulnerable, and for the prevention and control of disease, are related efforts.

A final assessment. The last sixty years has seen a growing sophistication in the way that food systems are understood, and in appreciation of the policies needed to maintain healthy, productive, and equitable food systems The current perspective is summarized in the following two diagrams. Figure 2.21 offers a graphical representation of the components of food systems addressed in this sub-chapter. The economic components of food systems include production, distribution and consumption. Factors influencing food production are land use and tenure, soil management, crop breeding and selection, crop management, livestock breeding and management and harvesting and storage. Food distribution involves a series of post-harvest activities including the processing, transportation, storage, packaging, trade and marketing of food as well as activities related to household purchasing power, traditions of food use, preparation, consumption and food waste management (including child feeding practices), food exchanges and gift giving. Activities related to food utilization and consumption include those involved in the preparation, processing and cooking of food at both the home and community levels, as well as household decision-making regarding food, household food distribution practices, cultural and individual food choices and access to health care, sanitation and knowledge, and other factors that may affect entitlement to food. It also includes the inputs needed and outputs generated at each step (IDRC 1999).

INSERT FIG. 2.21 HERE

Figure 4 is a graphic conceptualization of various activities that determine food security and nutritional well-being.

INSERT FIG.2.22 HERE

However, it may be questioned if sustainable, equitable, and safe food systems do in fact exist today (IDRC 1999). Over the last few decades, the structure of world food systems has changed dramatically as a result of horizontal and vertical integration of corporate interests in the food and agriculture sectors, and the globalization of both production and consumption (LaBelle, 2004). Food systems have changed from local or national systems to an increasingly integrated globalized system, from traditional artisan systems to industrialized systems, and to the increasing domination of market-based actors that operate under fierce price competition and processes of consolidation (Hendrickson & Heffernan, 2004). Food cultures, cultural identities, and even the traditions and knowledge associated with preparing food from raw ingredients, are eroding. Lyson (2004) enumerates six consequences: (i) loss of economic independence; (ii) greater concentration of production; (iii) loss of indigenous knowledge and genetic diversity; (iv) increased risks of food un-safety and accidents; (v) loss of rural communities; and (vi) loss of democracy.

While some see these trends as both inevitable and in fact the source of today's aggregate food surpluses, others note that only a handful of countries have actually reduced hunger since the World Food Summit. Moreover, they locate the source of the success of these countries in the value-driven political choices made rather than in autonomous technological or commercial drivers. Brazil's "Fome Zero" program and Viet Nam's nationwide program to eradicate poverty, are examples of what can be achieved through such deliberate policy choices.

## 2.4. Lessons from the Past: Implications for the Future

### *2.4.1. Main lessons learned.*

As defined in Chapter 1, AKST refers to all forms of knowledge used for agricultural purposes. As such, it is a combination of different knowledge, produced by numerous agencies and actors following their own agendas. The ultimate synthesis for action is made by farmers and other practitioners of agriculture, whose knowledge, as a result, has several important features which must not be forgotten, as is too often done, if one wants to elaborate a sound and comprehensive view of the numerous processes involved:

- It is 'place-based'. Local situations are always specific in some fashion. Relevant knowledge for action at the local level requires an understanding of what is location specific.
- It is 'embedded' in a web of institutional arrangements and relationships, at varying scales, such as farmers' organizations, industrial districts, commodity chains, etc. These relationships frame the farmers' opportunities and constraints. And thus farmers require a strategic ability to select and

interpret what is critical for their actions in these relationships.

- It is ‘collective’, not only because farmers learn together in group situations but also because they often are involved in collective actions of various forms, for which specific knowledge is required.
- In addition, the vast majority of farmers, particularly women, are often in disadvantaged economic, social and cultural situations, which may lead to disadvantages in their access to new knowledge and always requires an understanding of their social marginality.
- Finally, agriculture being by essence a ‘multifunctional’ activity, farmers need to know these multiple functions, how to perform them as well as the trade-offs between them.

The history of the last few decades shows that the outstanding successes of formal science and related technology developments in the 20th century led to neglect the paramount role of this synthesis among multiple knowledge components done by farmers for the conduct of their agricultural activities. This neglect can be attributed to scientific positivism as the dominant epistemological posture and the preference given by public program to the transfer of technology (ToT) model presented in the first sub-chapter of this chapter, leading often to a top-down vision of the linkages from research to farmers via extension where scientists hold the prominent position because they “know better” than farmers. The Chain-Link model presented in 2.1, where private firms generally play the leading role, remains close to the transfer of technology model, in as much as private firms remain in a very dominant position because they know the market for the final product which they sell and they want to ensure that the whole production/marketing channel operates in such a way as to satisfy the final consumer. However, in this model farmers get much scientific and technological information from private firms they buy from and sell to. This has led to a first recognition that multiple sources of knowledge are legitimately used by farmers and the next step was the recognition that farmers resort also to multiple kinds of knowledge, a logical implication of point 1, above.

In spite of these limitations, ‘modern’ science-based processes25 flourished in the 20th century. Working on a tight disciplinary basis, they led to large increases in the productivity of land without however addressing the organizational and social issues correlative to any kind of technical innovation. This is well illustrated by what has often been loosely called the ‘green revolution’. As a result of this major scientific and technological success, enough food for a rapidly growing population was produced in many developing countries with only a modest increase in the area of land under

[5] [2] The words ‘modern’ and ‘science’ used here are controversial, as reflected in the internal discussions among the lead authors of this chapter. Some would argue that science is not a monopoly of the professional scientists. Farmers and non-professionals can also be scientists, in the sense that they are often able to seek knowledge through a rigorous process, featuring the major components of a scientific approach. While accepting this premise, the terminology used here, consistent with the general glossary, distinguishes scientific knowledge and experiential knowledge and restricts the use of the word science to a form of knowledge produced by professional scientists following a scientific approach. The word ‘modern’ is more problematical because it may be interpreted as having an obvious positive connotation. In this historical chapter, the word is used as historians, at least some of them, do when they speak of ‘modern times’, a period beginning in the 18th or 19th century when philosophers and subsequently scientists played a leading role in intellectual debates. In that spirit, the current period, when the pre-eminence of scientists´ views for the solution of major societal issues is being questioned, could perhaps be called ‘post-modern’.

cultivation. This achievement not only contributed to the elimination of recurrent famines in Asia but also did that without the major damages to the environment which a large increase in the area of land under cultivation would have entailed. On the other hand, many social issues have been raised at national level such as exclusion of small owners, development of precarious jobs and eventually the swelling of shanty suburbs of already overcrowded cities that the green revolution contributed actively to feed.

The achievement just mentioned can be seen as a major milestone in modern history. Forty years ago, the specter of widespread famines due to a revival of the nightmare imagined by Malthus, a rate of population growth outrunning the food supply capacities, was looming large. Yet, the expression ‘green revolution’ is itself a lightning rod of great controversies. Three main criticisms have been expressed: the gains of the green revolution have been unequally distributed, it has had serious negative consequences for the environment and human health and it has contributed to a huge transfer of power over food production, processing, distribution and sales.

There is really little doubt that the distribution of the gains has been unequal. On a geographical basis for instance, fertile regions with access to irrigation (very often associated with an ancient tradition of social coordination) have benefited much more than les endowed regions. In many cases this has led to a widening of the income gap within agriculture and to the exclusion of the weakest. But it must be pointed out also that, where the green revolution has been a success, the poor have also benefited, mainly through an increase in the demand for their labor as illustrated in the 1970s by the mass movements of workers from Eastern India, where yields were stagnant, to the Punjab, where the green revolution was in full swing. The poor Biharis who were migrating benefited from these increased employment opportunities; and they would have been better off if the same employment opportunities had existed in their home region, i.e. if a green revolution had occurred there as well. Regarding the impact on poverty, one must also take into account the long term impact on the price of staple foods. The poor, both in urban and rural areas, are net buyers of food and they generally benefited from the lower prices permitted by increased volumes of production Yet it remains that more than 850 millions people, among whom mainly women and children, still suffer today from chronic food shortages. These contrasting impacts largely explain the controversies on this matter.

The impacts of the Green Revolution on the environment and on human health are even more controversial than those on income distribution and poverty. For the environment, the positive consequences of land savings mentioned above must be balanced against the negative impact of increased soil degradation and water pollutions due to fertilizer leaching and pesticide residues as well as the negative effects of irrigation (rapid draw down of ground water, much of it from historic aquifers that are not recharging; salinization of vast areas) In addition, there is strong evidence of negative impacts for biodiversity. On the health side, the benefits associated with improved nutrition, relative to what would have happened in the absence of a green revolution, must be contrasted with the damages to whole populations in areas of heavy pesticide use, as discussed in sub-chapter 2.3.

Beyond the controversies on these topics, one robust conclusion can be reached: the green revolution, which has essentially been a science-based process, has faced serious limitations. These must be overcome in the future. And, as discussed below, there are useful lessons to be learnt from past experience on how to do so.

The above shortcomings prompted the progressive development of new sets of international treaties and other regulations to limit or reduce the negative consequences. The Convention on Biodiversity (CBD) can be interpreted in that perspective. And so can the various Codes of conduct and guidelines on the elimination of highly toxic and safer use of pesticides. Furthermore, recognition of these shortcomings fuelled a number of forces, or 'drivers', (cognitive, policy, economic, market, technical, institutional) that encouraged knowledge innovations in new directions (e.g., ecological agriculture, LEISA, organic agriculture, IPM, etc.), relying on more participatory and place-based knowledge processes, giving a prominent place to farmers and their organizations, as discussed in detail throughout this chapter. These newer, typically participatory, ecologically-based knowledge processes have had both great successes and limitations. Yet, there is widespread agreement that new knowledge and new knowledge processes, participatory and place-based, will be needed to cope with the shortcomings of past efforts, regarding hunger, poverty, human health and the environment. This requirement will be made the greater by the magnitude of such new problems as the massive delocalization of rural populations and the rupture in intergenerational farmers' knowledge transmission. Despite the emergence of these new knowledge processes, their widespread adoption on a global scale has been limited, due to a wide and complex variety of factors (policy, market, trade, economic, institutional, technical, etc) – and so at present, the contribution of AKST to major development goals is not what it could be for a large share of the world's population (both rural and urban). On ethical grounds, such a situation can not be accepted.

As evidenced in previous paragraphs, many diverse actors are involved in knowledge processes; they form what have been called institutional arrangements. These have been very diverse in recent decades, as discussed in the presentation of the various knowledge process models in sub-chapter 1. These evolutions reflect the influence of various drivers, which have been illustrated in four different 'storylines', reviewing how several important problems, where AKST is centrally involved, have been tackled in the past. These storylines have illustrated the fact that the sets of actors partaking in innovation systems have evolved over time. Initially, for eons, farmers have been at the center. Modernity has brought in new actors such as state policy-makers, scientists (specialized in specific domains such as genetics, chemistry, biology, human health, and later on ecologists…), inputs suppliers and producers (specialized in pesticides, seeds, fertilizers,…), food processors and distributors in a progressive movement of division of labour. More recently, what can perhaps be called 'post-modernity' has seen a blurring of this division and the appearance of a new range of actors with five dominant categories of "agents": governments, civil society, public research, agrifood science industry, and farmers, who are forming a very diverse set of arrangements. Along with this evolution, the very scientific division between disciplines has been challenged and interdisciplinary approaches of scientific and technological issues have become unavoidable. The 'innovation systems' concept is useful to capture this complexity. In the words of Hall (2006): “It has been applied in other sectors, mainly in industry. The concept is considered to have great potential to add value to previous concepts of agricultural research systems and growth by (1) drawing attention to the totality of actors needed for innovation and growth, (2) consolidating the role of the private sector and the importance of interactions within a sector, and (3) emphasizing the outcomes of technology and knowledge generation and adoption rather than the strengthening of research systems and their outputs.”

It is clear that in the future multiple partnerships where farmers, individually and collectively, should often play a central role, are called for. But power relationships play an important role in institutional arrangements and sometimes these are not conducive to the genuine collaboration among unequal partners which would be desirable. Former mechanisms attempting to buffer these asymmetries (such as public bilateral and multilateral aid to agricultural development for instance) have been dramatically weakened. In addition, several institutions, particularly in developing countries, suffer from major dysfunctioning that limit or annihilate their ability to promote development and sustainability goals. By contrast, among the drivers mentioned above, two sets have emerged as particularly powerful in past decades: those associated with market mechanisms and those related to societal concerns. The importance of the former has been strengthened by a powerful movement of concentration of economic power in larger and larger corporations, often multinational, producing agricultural inputs and buying agricultural products, actually covering the entire food chain: seed supply, machinery and input provision, production, purchasing, processing, distribution, and retailing. In several subsectors these multinational firms have invested heavily in research, thereby changing radically the power relationship in the institutional arrangements for agricultural research. At the same time, societal concerns have been more and more expressed by civil society organizations, some of them having precisely been created because of these concerns. In some cases these organizations have become very powerful also, which partly explains why some of the controversies alluded to above have been so sharp.

### *2.4.2. Implications for future action.*

New institutional arrangements and changes in the realms of governance, policy, markets and trade environment will be needed to cope with existing problems and with the limitations of the respective knowledge processes that have emerged to date. Detailed discussions of these will be done in subsequent chapters of this report. Three main principles for action by public authorities, i.e., regarding policy reforms and institutional arrangements, emerge from this review of past experience:

- Because farmers are key players in transforming agriculture and in the AKST processes involved in such transformations, governments must give highest priority to creating the appropriate conditions for farmers and their organizations to play a leading role in AKST processes. This includes the establishment or strengthening of policies and procedures giving farmers and their organizations a true countervailing power in their relationships with other actors, particularly those of industry.
- Because scientists are other key players of this transformation and because the tension between the incentives faced by individual scientists and the societal demands placed on

scientific institutions has been growing in recent decades, governments must send them signals and incentives to orient part of their work towards societal issues with a priority to those who cannot express themselves through markets. In the same move, governments and research managers must create conditions to help scientists overcome academic divisions within ad hoc research arrangements.

- Because AKST processes have a key role to play in the future, and because evolution of societies and environment are tightly intertwined at the global level, governments need to ensure that enough resources, financial and human, are invested in AKST and that those resources are fairly and effectively distributed to ensure that the major dysfunctioning of the public institutions involved are corrected.
- Because private firms have also a key role to play, governments must ensure that the environment they provide to these firms is generally friendly to them, while setting clear and enforceable rules to guarantee the pursuit of the public good. In the case of AKST, this includes a well established role in the agricultural innovation systems and in particular appropriate and effective public-private partnerships, something of which successful examples are few and far between.