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Research for the innovation of the agri-food system in international cooperation

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Abstract

In the last few decades, characterized by intense environmental, landscape and socio-economic-financial changes, unexpected issues concerning the primary sector are arising and require researchers an urgent and deep reformulation of both the conceptual and technological tools used in the applied research. The concept of innovation is now radically changed, starting from a prevailing formula of linear top-down technology transfer, which has characterized the green revolution of the 1960s, to the nowadays approach that is characterized by the innovation of a complex system, and it is aimed at creating sustainable and shared opportunities through economic and institutional development. Those who now work in public or private bodies oriented to research for innovation are struggling to maintain their specific study area, but within integrated schemes where technical and scientific aspects are in interaction with organizational, institutional and political issues. Innovation can tackle several issues: new products, new technologies, new markets, new procedures (institutions) and new policies. The series of scientific and conceptual tools framed into the Agro-ecology domain seems appropriate to plan development initiatives of which the primary objective is ensuring a sustainable management of all the resources involved in agricultural production processes, while promoting food security and sovereignty, as well as protecting the rural landscape. By studying a target agro-ecosystem it is possible to identify and characterize the relationships between both the internal components and the system structures and functions at different levels of complexity of plot, farm and country, without neglecting the interactions among scientific, technological and socio-economic factors, and ultimately tending towards a science aimed at conflict resolution. Given the challenges that agricultural development is going to face in the next decades, it is indeed essential to support the planning and implementation of sound agro-ecological policies through an appropriate set of advanced tools. Particularly, a key aspect to empower all the stakeholders involved in the research, development, dissemination and application of new methods and technologies is the identification of information and communication systems that farmers and policy makers need in order to cope with fast-changing conditions in a complex system. University and research centers can act as institutional facilitators of dialogue and development policies among different stakeholders, catalyzing participation and promoting participatory problem-solving strategies for agricultural development and cooperation.

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The evolution of innovation in agricultural research and cooperation for development

Innovation is generally regarded as a solution of continuity with the past, *i.e.* a process of significant change and improvement of individual or social conditions. As written by Goldstone (1987) *the essence of innovation is trying something that has not been successfully done before, thus there is an unavoidable element of risk*. In an article published by the Economist in February 1999 innovation was defined as the *industrial religion of the late 20th century*. The article added *business sees it innovation as the key to increasing profits and market share. Governments automatically reach for it when trying to fix the economy. Around the world, the rhetoric of innovation has replaced the post-war language of welfare economics. It is the new theology that unites the left and the right of politics* (Valery, 1999). Moreover, the article stated that it was difficult to say what innovation is and, even more difficult, how to measure it. Paradigm, as stated by Kuhn (1962), is *a constellation of findings, concepts, values, and techniques shared by a scientific community and used by the community to define problems and legitimate solutions*. Some authors distinguish between invention, which is related to the birth of an idea for a new product or process, and innovation, covering the first attempts of application of an invention. As stated by Niels Röling (2009) innovation *is a sexy concept that appeals to left and right, and young and old, has promise, it sounds like a way forward* but it is also a *battlefield of knowledge* (Long, 1992) that requires a continuous updating of the basic concepts and the reference paradigm.

One of the main features of innovation, which until recently could be considered valid for all human productive sectors, is represented by the clear trend towards concentration in certain places and periods. This assumption is clearly valid in retrospect, as in every age it is possible to identify an *innovation leader*, whose role has been played by a group of states, a single state or a specific area within a state. As Goldstone stated in 1987, *in the 16th century, innovations in agriculture, navigation, finance and banking, textile and metal manufacture, and transportation were concentrated in Southern Europe, with major contributions coming from Portugal and Italy, particularly Venice, and to a lesser degree along the 'backbone' of Europe from northern Italy along the Rhine to the metal and textile centers of Flanders. In the seventeenth century, the same cluster of fields- agriculture, banking, transport, manufacture- were simultaneously carried forward in the Netherlands, providing the basis for that country's rise as a leading power. Finally, in the eighteenth century Britain became the locus of generalized innovation*. Germany and the United States of America would have later picked up Great Britain's baton.

On another hand historians, economists and sociologists characterized innovation as an intrinsically-urban phenomenon, as described by Hall (1998), with two main features: i) confluence in the same place for a critical mass of people and human capital; and ii) development of social networks supporting the exchange and circulation of ideas, experiences, points of view and then the emergence of new solutions and ideas. Both the network of relationships and the type of contacts within innovation itself are fundamental component of innovation, as stated by Granovetter (1973) in his work on the *strength of the weak ties*. Primitive and ineffective social networks prevent creative people to meet, while homogeneous and too stable networks generate relationships among people who are indeed too similar and not able to work as generators of diversity. Therefore, before examining the specific topic of research for innovation in the agri-food system, it is useful to summarize a historical analysis of this concept since the origins of the so-called Green Revolution, which marks the 1960s and 1970s and is still being invoked by some researchers as conceptual framework to be applied in future innovation processes.

An historical overview of agricultural research for development: from green revolution to the re-discover of traditional knowledge

Everett Rogers in the 1970s coined the *Diffusion of Innovation* phrase, referring particularly to the introduction of hybrid corn in the U.S. Corn Belt mainly in Iowa from the 1940s (Ryan and Gross, 1943) up to the 60s. The specific conditions existing within the North American system of production, the presence of university and research centers and the relationship between different production sectors in the Corn Belt allowed the development and test of: i) an innovation pattern based on genetic gene revolution manipulation and crop intensification; and ii) a diffusion process able to multiply the impact of research and dissemination *i.e.* extension. In a few decades, thanks to the adoption of hybrid corn, developed in some universities following the concept of plant ideotype and applying innovative techniques of genetic improvement, crop physiology and agronomy, many farmers were able to significantly increase corn yields, specializing themselves and simplifying their agronomic production schemes to meet the requirements of a growing market. This process allowed the testing and optimization of a system that served as a conceptual framework to launch the Green Revolution outside of North America, an event that took place under the following conditions (Röling, 2009):

- a large number of actors farmers and/or farms produced the same commodity for the same market;
- each of these actors was too small to affect the price of the commodities, so they were all in competition with the current price and constantly trying to improve their economic balance through production increases, possibly at a lower cost;
- due to inelasticity in demand for the most of farm products, every attempt to efficiently increase production exerted a downward pressure on prices;
- all farmers had access to credit, fertilizers, various information sources newspapers, extension agents and were members of organizations or associations.

In such conditions, a new innovative technology conveyed along with a concrete product, such as hybrid corn, could produce an *innovation wave*, *i.e.* an innovation process, that can be represented by an S-curve which describes the growing trend: slow at first, then much more quick and finally stabilized or decreasing. In the Corn Belt, these dynamics were the basis for a strong impetus to both agricultural research and the market. Analyzing what happened in the U.S. in the 1960s, Cochrane (1958) proposed the *Agricultural treadmill* theory, observing that in the early stages of diffusion of a technology the first small group of farmers able to adopt are going to achieve good results in a market still characterized by pre-technology conditions. When more farmers modify their production system by adopting the new technology, the state of the market changes as the total production increases, prices begin to fall, and eventually the farmers who had not yet adopted the new technology are forced to do so. These phases of the diffusion process have been described as *propelled by market forces,* defined as the *treadmill.*

In such conditions elder farmers and farms characterized by small dimensions or intrinsic weaknesses tend to sell or lease their resources *i.e.* land, thus promoting a growth towards an economy of scale for the whole sector, *e.g.* through an increase of the average size of the remaining farms. As highlighted by Röling (2009), the diffusion of innovation pattern within the treadmill system determines -when it works- a political model that implies important consequences at the macro-level, such as:

- migration from rural to urban areas farmers in industrialized countries currently account for only 4-5% of global workforce; about 10% when including agribusiness workers;
- farmers do not maintain permanent benefits of the technological innovation they adopt;
- countries becomes more competitive on the world market when their food industries becomes more efficient;
- the majority of farmers does not respond fast to innovations; the early adopters take the most of the benefits in particular gaining increases in their farm size and are generally able to exercise their leadership in farmers' organizations.

The model tested in the U.S. on corn had specific peculiarities: i) innovation was initially focused on a single product; ii) the advancement was developed by research teams with a very focused and precise set of objectives e.g. development of a crop variety with an increased production performance; and iii) the extension process followed a top-down approach towards the farmer groups, which could use the improved in terms of higher productive capacity product and adopt the whole technology package disseminated by the extension service facilities. Since the 1960s this innovation and technology transfer model within free market conditions became the model to be exported in the world with the aim of making agriculture develop everywhere. This approach was defined by Kline and Rosenberg (1986) as a *linear model* and by Chambers and Jiggins (1987a, 1987b) as *transfer of technology model*, implying thus that: i) it could be transferred without significant changes virtually in every corner of the world; ii) there was a single development pattern fitting all countries; and iii) there was a causal mechanism underlying the production, distribution and access to food processes, so that for solving food-related poverty issues it was necessary and sufficient to increase production yields, as happened in the original North American reference model.

Nonetheless, this ideal approach clashes against the non-linearity of the agri-food system and its linkages with the whole social, economic and environmental framework at multiple spatial levels. This bias resulted in a deep misinterpretation of agricultural externalities as well as the effects of market failures. With regards to agricultural externalities -meaning the benefits or costs not included in the market price of agricultural products- it should be said that the agriculture-driven pollution and depletion of natural resources, as well as other health, social and environmental costs, are partially counterbalanced by a number of public benefits, even though there is no comprehensive assessment framework for the latter ones (Pretty *et al.,* 2010). The recent study of Pretty *et al.* (2010) globally estimated the cost of agriculture externalities in US$ 81-343 per hectare of arable land and grasslands, and the positive benefits in the range of US$ 16-49 per household. Among the most serious examples of negative impacts of agriculture, the pollution of groundwater resources and water ecosystems (Conway and Pretty, 1991; Donoso *et al*., 1999; Pimentel *et al.,* 1992; Pretty *et al*., 2003) as well as soil erosion and loss (Evans, 1996; Holmes, 1988; Pimentel *et al.,* 1995) are mostly reported; negative effects on human health due to the intensive monocropping and livestock is also increasingly debated (Altieri, 1995; Horrigan *et al*., 2002; Phillips *et al*., 2004); finally, agricultural-induced loss of biodiversity is increasingly recognized as a serious threat for the future generations (McLaughlin and Mineau, 2000; Dupouey *et al*., 2002; Reidsma *et al*., 2006). On the other hand, agriculture can provide various benefits other than the provision of food, feed, fiber and fuel (Millennium Ecosystem Assessment, 2005; OECD, 2001), especially when policy makers can adequately support the expansion of agricultural multifunctionality. Indeed, among the most important positive impacts of agriculture there are important agro-ecosystem functions seeking to optimize the management of natural resources, meaning land, air and water. Within this framework, agriculture can play a key role to increase the sustainability of urbanization processes (Batie, 2003; Diakosavvas, 2008; Heimlich and Anderson, 2001; OECD, 1998), improve soil organic matter through nutrient-use efficiency practices (Cassmann, 1999; Cassmann *et al.,* 2002; Matson *et al.,* 1998; Tilman *et al*., 2002), and promote the reduction of greenhouse gas emissions (Cole *et al.,* 1997; Niggli *et al.,* 2009; Smith *et al.,* 2007, 2008) as well as carbon sequestration (Antle and Stoorvogelm, 2008; Freibauer *et al.,* 2004; Morgan *et al.,* 2010; Ramachandran *et al.,* 2009). One of the main consequences linked to such a dichotomy of agricultural benefits and externalities is the high complexity characterizing the development and implementation of adequate policies able to balance these costs and benefits (Pretty *et al.,* 2010; Swinton *et al*., 2007; Zhang *et al.,* 2007).

More broadly, the agricultural sector has been frequently characterized by market failures, which are primarily seen as the inefficient allocation of goods and services by the whole agricultural production, specifically meaning its externalities (OECD). Market failures are also linked to other three main causes, such as: i) the impossibility to lend public goods (*i.e*. agricultural benefits) on the market, as referenced in the previous paragraph; ii) the lack or distortion of information about an agricultural good or service, as well as the insufficient and asymmetric access to the necessary agricultural market information at both the producer (King, 1985) and the consumer level (Caswell and Mojduszka, 1996; Hennessy, 1996; Verbeke, 2005); and finally iii) imbalances in market power (Ribaudo *et al.,* 2008b), leading to barriers -especially for smallholder farmers, at both the entry (Dorward *et al.,* 2002; Kherallah and Kirsten, 2002) and the exit of agricultural markets (Bunje, 1980).

If government intervention has been a traditional answer to most kinds of market failures in agriculture (Alston *et al.*, 1998; Besley, 1994; Timmer, 1989; Yaron *et al*., 1997), on the other hand the market itself could play a role in mitigating market failures, particularly the negative impacts of agricultural production, through the quantification of externalities and the establishment of a formal trading for ecosystem services (Ribaudo *et al.,* 2008a; Tegtmeier and Duffy, 2004). Moreover, the role of private-public partnerships is increasingly becoming central to the promotion of innovation and agricultural research for development (Hall *et al*., 2001; James, 1997; Mitchell-Weaver and Manning, 1991; Spielman and von Grebmer, 2006).

Hall (2006) summarizes the innovations or innovative processes as follows:

- *innovations are creations of social and economic significance that may be brand new, more often combinations of existing elements;*
- *innovation can comprise radical improvement, but usually consists of many small improvements in a continuous process of upgrading;*
- *these improvements may be of a technical, managerial, institutional or policy nature;*
- *innovation involve a combination of technical, institutional, and socio-economic changes;*
- *innovation processes can be triggered in many ways bottlenecks in production, changes in available technology, competitive conditions, international trade rules, domestic regulations and environmental health concern.*

Before considering how and when the innovation concept has marked an evolution in the last 50 years it is appropriate to clarify some fundamental points.

There are different product, process and system innovations. Some authors also distinguish the singular *innovation* from the plural *innovations*. Innovation should be framed into the broad range of activities and processes linked with the creation, dissemination, adoption and use of new technological, institutional and managerial knowledge that determine technical, social, economic and environmental changes. Innovation can thus be related to the development of new products, new technologies, new markets, new institutions or new policies. The World Bank (2006) defines *innovation system* as *the system that comprises the organizations, enterprises and individuals that demand and supply knowledge and technologies, and the policies, rules and mechanisms that affect the way in which different agents interact to share, access, exchange and use knowledge*. As a result, innovation appears as the emergent property of interactions between the stakeholders of a given system.

The modern concept of innovation implies institutional and technical innovation, hence it is the combination or integration of the above two dimensions of innovation that nowadays requires inter-sectorial and interdisciplinary studies.

It is appropriate to overcome some false dichotomies that may weaken the debate on innovation, such as: i) endogenous or local innovation *vs.* induced or external innovation; ii) innovation focused on technique or technology advancement *vs* institutional change; iii) traditional or indigenous knowledge *vs* scientific and modern knowledge; iv) technology-driven innovation *vs* demand-driven innovation; and v) pragmatic market and technological innovation *vs* system idealistic innovation. These dichotomies, which reveal a simplistic approach, are often part of the same system and therefore do not allow the development of truly innovative research agendas.

Table 1 shows a diagram summarizing the stages of evolution of the concept of innovation in agriculture.

The evolution in the Research and Development approach in agriculture led to the concept of *Integrated Agricultural Research for Development*, IAR4D. The *innovation system approach* concept shifts the focus from research and provision of knowledge and technology towards an interactive multi-stakeholder change process. Technology dissemination and market development are simply some of the elements of the system.

With regards to the innovation concept, the historical tendency was the constant updating of this notion through decades: the meaning of innovation changed from the early push of new technologies to the recent creation of opportunities through institutional development. This implies that the concept of innovation in agriculture, along with its related challenges and opportunities, needs to be framed in an integrated set of technical, organizational, institutional and political elements. As a result, there is a need to move beyond the old linear model for the diffusion of innovations, which is nonetheless still taken up and raised by various international initiatives.

A focus on participation in innovation processes in agriculture

In several studies dedicated to the topic of innovation in agriculture it is highlighted that the learning capacity of stakeholders is the critical point in most of the systems aimed at promoting innovation. Innovation processes must be strengthened at all levels, to the benefit of all system stakeholders including farmers, extension agents, consultants and researchers – all together defined as innovation *students* (Hagmann, 2002; Hall, 2007). With this approach it is possible to create links, relationships and alliances among innovation actors. This set of relationships is based on the principles of mutual learning, resource and knowledge sharing in ways aimed at facilitating institutional change. This kind of partnership was recently defined as *participation* and indicated as one of the five guiding principles of the activities (Table 2) promoted by the European Initiative for Agricultural Research for Development EIARD.

The right to participate in decision-making is also recognized as a human right in Article 25 of the International Covenant on Civil and Political Rights see also E/C.12/1999/5, under the *right to food* section. Among the various farmers' rights included in the International Treaty on Plant Genetic Resources for Food and Agriculture there is *the right to participate in making decisions, at the national level, on matters related to the conservation and sustainable use of plant genetic resources for food and agriculture,* article 92c. Farmers should be actively involved in preparing and drafting legislation that affects certification and market of seeds, conservation of genetic resources, as well as protection and patents laws.

According to Pimbert (2011) participation can be described in different ways, with respects to its kind of relationships and research activities, as indicated in Table 3. Pimbert defines an additional form of participation, defined *auto-mobilization*, when communities participate by taking independent initiatives, unrelated to the external institutions, in order to change the existing conditions. This form is close to the Landcare experience (Campbell, 1994) where Australian farmers and landowners drove an autonomous innovation process to face soil

Table 1. Evolution in the Research & Development approach in agriculture adapted from Scoones *et al.*, 2008.

Approaches / Features	Technology transfer	Farming system research	Farmer participatory research FPR	Innovation system
Period	*Until the 1960s*	*Beginning of 1970-80s*	*Beginning of 1990s*	*2000s*
Mental models and activities	Provide technology through pipelines	Understand the constraints of local farms through spatial surveys	Collaborate in the research and development	Develop joint research involving stakeholders in multiple partnerships and processes
Discipline-specific knowledge	Determined by a single discipline genetics	Multi-disciplinary agronomy and agricultural economy	Inter-disciplinary with social scientists and expert farmers	Trans-disciplinary analysis of complex system
Objectives	Production increase	Efficiency improvement	Provision of adequate livelihoods to the farm	Promote value chains and institutional change
Main elements	Technology packages	Technology packages updated to overcome constraints and obstacles	Joint production of knowledge and technologies	Promote value chains and institutional change
Drivers	Research offer	Assessment of boundaries and limits of farmers	Farmers' demand	Responsibility for change
Innovators	Researchers	Researchers and extension agents	Farmers and researchers	Multiple stakeholders forming an innovation platform
Role of farmers	Adoption or refusal	Information source	Active test agents	Partners, business agents, innovators
Role of scientists	Innovators	Experts	Cooperators	Partners as one of the parties answering to the needs
Perceived key changes	Behavior of farmers	Removal of the main constraints for farmers' work	Strengthening of farmers	Institutional change, innovation capacity
Expected results	Adoption of technology	Adjustment of the farm system	Co-evolution of technologies with a more appropriate livelihoods system	Capacity to innovate, learn and change
Sustainability	Indefinite	Important	Explicit	Priority, regulated and multidimensional

erosion, salinization and desertification resulting from the previous inappropriate adoption of European agricultural techniques in the Australian environment. This innovation process, ignited by the need to develop new site-specific land management techniques and to reactivate ecosystem services at landscape scale, required a great collective effort, joint action, new organizational structures and infrastructure, social learning and participation. This kind of innovation was then replicated in other sectors, *e.g.* in watersheds and communal forests management, and it is now widespread.

Innovation can also be described as the emergent property of interaction among stakeholders in a natural resources or economic system service (Bawden and Pacham, 1993) and as Röling (2009) observed: *where the degradation of the resource or service is the collective outcome of each stakeholder's trying to satisfy his/her individual preferences, more sustainable management of the resource or service necessarily must emerge from collective processes – social learning, conflict and negotiation, agreement, reciprocal sacrifice or benefits and privileges, and leadership – that lead to concerted action* and *when innovation is the emergent property of interaction, promoting innovation becomes a matter of facilitating the interaction process, and the institutional support and favorable policies at higher level are essential ingredients for success at the local level*. This last element is strictly connected to the epoch-making article appeared on Science in 1968 *The tragedy of the commons* (Hardin, 1968).

A comparison of innovation systems and platforms targeting the agri-food sector in developing countries

*Grassroots Agricultural Innovation (*GAI) has been used to indicate both interfaces and forms of integration of endogenous and exogenous innovation in the farming systems of sub-Saharan African small farmers and pastoralists, which is an area characterized by subsistence agriculture. Within this framework, the dynamics of interaction between exogenous innovation originated by external actors such as NGOs, research centers and external donors and endogenous innovation, *i.e.* originated by individual and small groups' facing poverty and environmental issues, are particularly complex. In order to better ana-

Table 2. The five European Initiative for Agricultural Research for Development driving principles.

Guiding principle	Formulation of the contents of EIARD
Partnerships	Promoting equality and mutual respect between partners from Europe and the South. Increase national and regional capacity to plan and implement effective agricultural research.
Complementarity	The actions implemented within the framework of agricultural research for development must be complementary and add value to EU-South bilateral actions.
Subsidiarity	Research activities must be designed in agreement with the goals, and must be planned and implemented at the simplest level of implementation and effectiveness.
Relevancy	The actions must meet the demands of the South, considering the economic, social, cultural conditions of the involved countries. Actions must also fit the priority needs and the research capacity of the target users.
Participation	The cooperation of all stakeholders (*i.e.* institutions, researchers, extension services, farmers, civil society, private sectors, *etc.*) is required.

EIARD, European Initiative for Agricultural Research for Development.

Table 3. Type of participation (Pimbert, 2011).

Type of participation	Description
Passive participation	Target communities are involved through information actions describing what is happening. Central governments or project managers disseminate unilateral announcements, without special attention to the feedback. Information is shared through external professionals.
Participation in the provision of information	Target communities participate to communication activities by answering questionnaires prepared by the project staff. Target actors have no chance to influence decision-making. Research results are not shared with the communities.
Participation through consultation	Target communities are consulted. External staff assists in defining problems and solutions by updating them according to the feedback provided by target communities. There is no sharing in decision-making.
Participation for material incentives	Target communities participate by providing resources to the project *e.g.* work in exchange of food, money, materials. Many on-site research projects fall under this category. The farmers provide their fields, but they are not involved in experimentation and learning processes. Target communities have no chance to autonomously carry on project activities when the project ends and there are no more related incentives.
Functional participation	Target communities participate by composing groups to achieve the primary objectives of the project. This activity is often started during the second phase of the project, when the initial stages of *project cycle* and *planning* is concluded and all the major decisions are taken.
Interactive participation	Target communities participate in the joint analysis that produce action plans, which in turn leads to the creation of local groups or the strengthening of the existing ones. Interdisciplinary methodologies are employed in order to reach different goals, by making use of systematic and structured learning processes. The community groups own local decision-making and are likely to autonomously implement project practices after the end of the development initiative.

lyze this element, it is interesting to compare three different approaches to innovation systems in agriculture (Assefa *et al*., 2009): National Agricultural Research System (NARS), Agricultural Knowledge and Information System (AKIS), and Agricultural Innovation System (AIS) (Table 4).

The development of the AKIS concept was a response to the activity of the NARSs, which had the main goal of technology transfer to developing countries and followed the typical linear model of the Green Revolution. Within the NARS approach there is no distinction between invention, innovation and knowledge, being the NARS based on the assumption that scientific research is the only knowledge supplier and thus promoting the activities of research and development centers. AKIS aims to enhance communication and relationships within stakeholders' systems, firstly by not considering the farmers as mere consumers of technology produced by the research sector and disseminated by extension services, but rather as active components of the creation, dissemination and use of knowledge. Thanks to the shift from the linear model to the *multiple sources of innovation* MSI model paradigm, many new experiences of agricultural research for development were designed and implemented, such as the *Rapid Appraisal of Agricultural Knowledge Systems* RAAKS, the *Farmers Field Schools* FFSs, the *Participatory Technology Development* PTD and the *Participatory and Innovation Development* PID concepts. It can be observed that the general AKIS approach remains focused on the research supply concept, strongly highlighting the importance of links among actors who are all seen on the same level. Nevertheless, the influence of policies and other social forces on innovation and knowledge is not considered, hence proposing a not entirely realistic framework (Leeuwis, 2004; Hall, 2006). On the contrary, these influences are taken into consideration by the AIS approach, which offers a basic explanation of how innovation occurs, as well as how and who achieve the benefits of complex technological and institutional change processes. Within this framework, an *innovation system* has been defined as *a network of organizations, enterprises and individuals focused on bringing new products, processes and forms of organization into economic use, together with the institutions and policies that affect their behavior and performance. AIS not only does embrace the science suppliers but the totality of the actors involved in innovation* (Assefa *et al*., 2009). The AIS concept in the literature is presented as a framework for analysis and planning as well as for assessment and processes of building/strengthening innovation capacity. So far, the AIS approach has been used to analyze innovation for market-related issues, while it was not adapted to study innovation processes within the so-called social and environmental capital dimensions. As a result, the issues linked to the relationship between innovation and empowerment, environment and sustainability have been underestimated.

The concept of *innovation platform* refers to a set of actors and stakeholders linked because of their individual interests with respect to goals, challenges and opportunities: facing these common issues represents the chance for improving their conditions *e.g.* subsistence livelihoods, entrepreneurship initiatives, *etc.* There are examples of innovation platforms, or similar research initiatives for development that can provide the basis to verify if AIS approach is more effective than the conventional methods. Among these initiatives, it is useful to mention: the Department For International Development DFID *Research Into Use* Programme; the *Forum on Agricultural Research of Africa* FARA *Sub-Saharan Africa Challenge* Programme; the Innovation Units of the International Livestock Research Institute ILRI; the Innovation and Development Unit at the Research Centre for International Development CIRAD; and the *Global Partnership Programme Promoting Local Innovation in ecologically oriented Agriculture and Natural Resource Management* Prolinnova operating within the Global Forum on Agricultural Research GFAR. Most of these initiatives are still in their inception or development phase, hence not allowing yet to respond to the criticism raised by some research centers, such as the question *whether the AIS approach works outside the test environments and whether it can deliver more benefit to a large number of farmers more quickly than do conventional approaches* (CGIAR*, 2007).

**Consultative Group on Agricultural Research*

Table 4. The National Agricultural Research System, Agricultural Knowledge and Information System and Agricultural Innovation System approach to innovation in agriculture adapted from Hall, 2006 and Assefa *et al.*, 2009.

Defining feature	NARS	AKIS	AIS
Purpose	Planning capacity for agricultural research, technology development and technological transfer.	Strengthening communication and knowledge delivery service to rural people.	Strengthening capacities to innovate the agricultural production and marketing system.
Actors	National agricultural research organizations, agricultural faculties/departments in universities, extension services and farmers.	National agricultural research organization, agricultural faculties/departments in universities, extension services, farmers, NGOs and rural entrepreneurs.	Potentially all actors in public and private sectors involved in creating, diffusing, adapting, using all types of knowledge.
Outcome	Technology invention and technological transfer.	Technological Adoption and innovation in agricultural production	Combination of technical and institutional innovation.
Organizing principle	Employ science and scientific research to create inventions.	Accessing agricultural knowledge.	New uses of knowledge for social and economic change.
Mechanism for innovation	Transfer of technology.	Interactive learning.	Interactive learning.
Degree of market integration	Nil	Low	High
Role of policy	Resource allocation and priority setting.	Enabling framework.	Integration and enabling framework.
Nature of capacity strengthening	Infrastructure and human resource development.	Strengthening communication among stakeholders in rural areas.	Strengthening interactions among stakeholders. Learning and innovation creating an enabling environment.

NARS, The National Agricultural Research System; AKIS, Agricultural Knowledge and Information System; AIS, Agricultural Innovation System.

Given that innovation is a complex and adaptive process, requiring an appropriate period of time and resources to carry out a significant assessment over its linkages to empowerment, environment and sustainability issues, it seems that an appropriate logical and a rigorous conceptual framework would be needed. With regards to the agricultural sector, agro-ecology represent an ideal approach to this fill this gap.

An agro-ecological framework for agricultural cooperation for development

The aforementioned *battlefield of knowledge* requires a continuous updating of the basic concepts and the reference paradigm, as well as defining the appropriate strategies to select conceptual and pragmatic tools. Mac Rae *et al*. (1989) suggested the following scheme with three levels of innovation strategy (Table 5).

At the first level, called *substitution strategy*, existing farming systems are only slightly adapted and not modified in a substantial way; the size of plots is usually at the scale of experimental activities; research activities are driven by a single discipline. At the second level, the strategy aims at *building innovative technical scenarios* relying on biological regulation in integrated crop production schemes; the research works at farm or regional scale within the agro-ecological framework and with a multidisciplinary approach.

At the uppermost *global level*, interdisciplinary and inter-sectorial research is carried out with the aim of tackling agricultural issues at the global scale, rethinking the relationships of agricultural sector to the society as a whole or focusing on specific issues, such as intensive agriculture and its links to the economic-industrial model or its failure in sustainability terms, new trends in agro-ecology and new scales *of agronomic research, ranging from foodshed to large regional areas.*

Agro-ecology is gaining importance and it has been acknowledged as a strategic approach for pursuing sustainability in natural and agricultural system management, particularly through the consolidation of stability and resilience of the natural ecosystems. Indeed, the series of scientific and conceptual tools framed into the agro-ecology domain seems appropriate to plan development initiatives of which the primary objective is ensuring a sustainable management of all the resources involved in agricultural production processes, while promoting food security and sovereignty, as well as protecting the rural landscape. By studying a target agro-ecosystem it is possible to identify and characterize the relationships between both the internal components and the system structures and functions at different levels of complexity of plot, farm and country, without neglecting the interactions among scientific, technological and socio-economic factors, and ultimately tending towards a science aimed at conflict resolution.

Given the challenges that agricultural development is going to face in the next decades, it is indeed essential to support the planning and implementation of sound agro-ecological policies through an appropriate set of advanced tools (Bocchi and Sala, 2009). Particularly, a key aspect to empower all the stakeholders involved in the research, development, dissemination and application of new methods and technologies is the identification of information and communication systems that farmers and policy makers need in order to cope with fast-changing conditions in a complex system. This is particularly true for low-income smallholder farmers, such as in Africa where the majority of farmers do not have access to the scientific and technological advances that support agricultural decision-making because of the lack of reliable communication networks (Boulahya *et al.,* 2005).

One of the biggest issues faced by the scientific community is the identification of proper tools to reach final users meaning both rural communities and policy-makers with the latest advances in research. Knowledge and information on complex issues *e.g.* agro-ecology and climate change often do not respond *per se* to the short-term needs of marginalized communities; moreover, there is a lack of a communication systems based on formats and languages that local communities can comprehend, as well as a trustworthy communication channel with scientists and extension agents able to appropriately disseminate solutions. Environmental information and communication systems can be a key tool in supporting food security, providing early warning, monitoring, forecasting and crop insurance, among the others (Brown *et al.,* 2007). Nevertheless there are important issues to be solved in order to exploit the potential of information and communication tools in these fields, especially when tackling cross-cutting issues, such as the existing gap between the informative outputs of global information systems and the requested inputs for impacts and natural resources management at local level; the technical and knowledge distance among different working groups; and finally the lack of effective integration between research and policy. With regards to this last issue, it will be essential to support the collaboration among scientists and policymakers: this can be facilitated through decision support systems, particularly if coupled with Geographic Information Systems (GIS) and other tools aimed at conducting quantitative analyses of trade-offs given a set of policy options (Ingram *et al*., 2008). With the same perspective in 2001 the IPCC underlined the local conditions that could determine if a

Table 5. Levels of innovation strategy adapted from Mac Rae *et al.*, 1989.

Levels of innovation strategies	Meaning	Example	Scale of research and disciplinarity
Substitution strategy	Existing farming systems are only slightly adapted and fundamentally not altered (Rosset and Altieri, 1996).	Toxic chemicals and fertilizers should be replaced by less pollutant, less persistent in soil and less energy-consuming compounds.	Plot; Monodisciplinary.
Agro-ecological strategy	Build innovative technical scenario relying on biological regulation in integrated crop production scheme (Altieri, 1987, 1999).	Applying ecological concepts and principles, *e.g.* biodiversity, intercropping rotation, agroforestry.	Farm or large territory; Multidisciplinary agronomy, landscape ecology, geography, *etc.*
Global strategy	Solve agricultural issues at the global scale, rethinking its relation to society. Failure of intensive agriculture are linked to its economic-industrial model. New trends in agro-ecology (Gliessman, 2007).	Studying the relationships between production and marketing; linkages farms and consumption; marketing networks.	Foodshed, regional, Inter-disciplinary, trans-disciplinary, cross-sectorial agronomy, ecology, sociology, economics, politics.

community is likely to be able to adapt to changes: among the others, the *ability of decision-makers to manage information* was stressed. To face these challenges the linkages between agriculture and Information and Communication Technologies ICTs are increasing in both quantity and granularity, until the recent birth of an autonomous sector, called *E-Agriculture* (Electronic Agriculture), characterized by the application of ICTs to strengthen agricultural and rural development through better management of data, information and communication processes throughout the production, distribution and consumption of the agri-food system products. Among environmental information systems and technologies, GIS and remote sensing techniques are particularly relevant thanks to their features enabling the development of studies at different temporal and spatial levels by integrating data and information (Thornton *et al,*. 2007; Bocchi *et al.,* 2006): through GIS it is possible to manage large amounts of data, including databases, models and traditional digital maps; their application allow a fast cross-sectorial interaction as well as the production of synthetic information for decision-makers (Maracchi *et al.,* 2000). Remote sensing techniques offer an ideal side for the development of criteria and indicators to assess the sustainability of agricultural practices for food production and natural resources management. Some attempts in this sense have been carried out in the recent past (van Mansvelt and van der Lubbe, 1999), but the range degree of local agro-ecological peculiarities make the development of exclusive solutions particularly tricky (Lopez-Ridaura *et al.,* 2005). Nevertheless, it is likely that the combination of these technologies, coupled with advances in monitoring agro-ecological resources through increased availability of expert and non-expert user generated content, will be particularly important for the design of agro-ecological policies. The key role of information and communication as an integral component of agricultural research for development initiatives becomes clear when looking at concrete examples. The United States Agency for International Development (USAID) *Middle East Water and Livelihoods Initiative*, a project supporting the improvement of rural livelihoods through sustainable land and water management in the Middle East* that is presented in further on, highlighted the need for establishing a *Research Continuum* among project stakeholders through improved information and communication practices. Particularly, the project identified the need to strengthen integration among the main pillars for sustainable agricultural development at different agricultural research systems levels, and more specifically the outputs of research in natural resources management, crop improvement and the socio-economics and policy studies, as a precondition for project success. Thanks to this approach, the establishment of linkages between research and development for sustainable impact had been put in place (sketch referenced in Figure 1) linking farmers communities to research institutes and policy makers at both national and international level, enhancing and balancing responsibility for communication among the involved project stakeholders.

**Project is being implemented in: Egypt, Iraq, Jordan, Lebanon, Syria, the West Bank and Gaza, and Yemen.*

Partnerships for innovation in agricultural research for development

In an environment characterized by increasing complexity due to the intersection of human activities and natural resources conservation needs, it is fundamental to highlight the role of partnerships addressing food production issues in different markets, food security and production stability, access and participation of different actors to development research processes.

In this regard, institutional networks working at different levels, particularly regional *consortia* are currently growing in both terms of capacity and resources. Furthermore, universities and research centers continue to act as key stakeholders for both their experimental and training activities. Indeed, university and research centers can act as institutional facilitators of dialogue and development policies among different stakeholders, catalyzing participation and promoting participatory problem-solving strategies for agricultural development and cooperation.

A focus on European regional networks

In 1995, the *European Initiative for Agricultural Research for Development* EIARD was established by the European Union with the aim of coordinating the actions of individual states in research for development in agriculture and especially to improve relations with the international research centers from the CGIAR (EIARD-Infosys+, 2011). CGIAR is composed by 64 members that organize and fund 15 international agricultural research centers aimed at contributing *to achieve food security and poverty eradication in developing countries through research, partnerships, capacity building and support to policies, promoting sustainable agriculture based on sound natural resources management* and with the objective of delivering international public goods as research products and research for development activities that does not respond to an immediate interest by the private sector.

Several public and private agencies are currently dealing with agricultural research for development. Among the others, European Consortium on Agricultural Research in the Tropics ECART is aimed at improving coordination among research activities in the European Union. Within the framework of ECART activity the European Economic Interest Group ECART-EEIG was funded, consisting of 8 members: CIRAD, Overseas Agricultural Institute IAO, Italy, Instituto Investigaçao Cientifica Tropical de Portugal IICT, Portugal, Instituto Nacional de Investigacion Agraria y Alimentaria y Tecnología INIA,

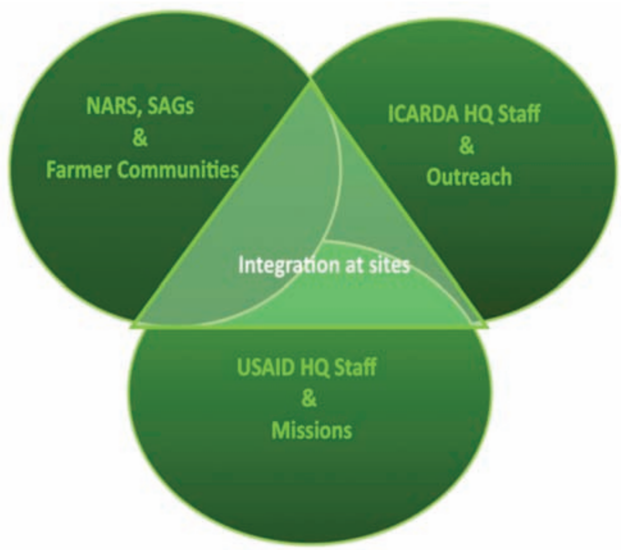

Figure 1. Communication in the Middle East Water and Livelihoods Initiative.

Spain, International Research for Development IRD, France, Natural Resources Institute NRI, United Kingdom, Wageningen University and Research Centers WUR, The Netherlands. ECART has worked in close contact with regional research networks, such as the West and Central African Council for Agricultural Research and Development CORAF/WECARD and the Association of Strengthening Agricultural Research in Eastern and Central Africa ASARECA, with NARS and the FARA and with other European institutions, such as the General Directorate of Research and the General Directorate of Development. ECART, along with the Network of European Agricultural Tropically and Subtropically Oriented Universities and Scientific Complexes Related with Agricultural Development NATURA, is responsible for the monitoring and evaluation of CGIAR activities funded by the European Commission. ECART participated also in the development of EFARD European Forum for Agricultural research for development, which is in charge for the implementation and management of the Platform for African-European Partnership on Agricultural Research for Development PAEPARD.

Since 2009, ECART and NATURA joint into a single network named AGRINATURA, composed by an Association, open to all European agricultural research and education organizations, and a European Economic Interest Grouping AGRINATURA-EEIG, as its operational arm. AGRINATURA currently involves 31 members from 18 European countries. Particularly, these institutions seek to promote the strengthening of partner universities and national research centers in the South, as well as improving coordination for a successful use of the Members' scientific and technical potential. Even at the sub-national level there are various examples of networks operating in the field of Agricultural research for development, such as the *Interuniversity Centre for Food and Agricultural Development Cooperation* CICSAA, founded in Italy by the Universities of Milano, Pavia, Brescia and Torino. Most of the EU-funded thematic networks are made up of universities or research institutes that operate in the same scientific field, such as the *Bureau for the Development of Research on Tropical Perennial Oil crops* BUROTROP or the European Tropical Forest Research Network ETFRN. There are also other initiatives like the *Young Professional Platform on Agricultural Research* YPARD, established by the Third Conference of the European Forum for Agricultural Research for Development, the *International Centre for Development oriented Research in Agriculture* ICRA, and the *Technical Centre for Agricultural and Rural Cooperation* CTA, created between European Union and ACP countries *i.e.* countries from Africa, Caribbean and the Pacific under the Cotonou Agreement in order to increase research and development on information and communication as well as to strengthen information and communication channels among members.

Regional and sub-regional organizations in developing countries

Regional or sub-regional organizations SROs are non-governmental organizations established by the local NARS in developing countries to make the research more efficient and effective through coordination actions among different states in the same region. Among these organizations there are the *Association of Agricultural Research Institution in Near East and North Africa* AARINENA, the *Asia Pacific Association of Agricultural Research Institutions* APAARI; the *Central Asia and Caucasus Agricultural Research Institutions* CACAARI; the *Foro Regional de Investigacion y Desarrollo Tecnologico agropecuario* FORAGRO; and FARA. Specifically, FARA is composed by four sub-regional agricultural research organizations: the *Association for Strengthening Agricultural Research in Eastern and Central Africa* ASARECA, the *West and Central Council for Agricultural Research and Development* CORAF/WECARD, the *Southern Africa Center for Cooperation in Agricultural research and Training* and the *Association for Agricultural Research in Near East and North Africa/North of Africa* AARINENA/NoA. The purpose of FARA is to reduce poverty in Africa as a result of sustainable agricultural growth and improving living conditions in a particular way for the small farmer. The three main objectives of FARA are the promotion of the importance and the role of research in agriculture, the development of functional partnerships and the facilitation of technology sharing and exchange.

The experience of the USAID Middle East Water and Livelihoods Initiative

The Middle East Water and Livelihood Initiative (WLI) was designed and funded by USAID in order to tackle the continuing overuse of water and consequent on-going degradation of agro-ecological systems forms the single largest concern facing farm households, rural communities, and natural resources in all countries of the Middle East. Particularly, the competition for freshwater has played a defining role in political relationships of the Middle East for thousands of years, threatening economic development, food security, and stability in many parts of the region. For this reason, having identified water scarcity as the key constraint to the improvement of rural livelihoods, USAID decided to address this issue in seven different countries of the region Egypt, Iraq, Jordan, Lebanon, Palestine, Syria and Yemen through the development and implementation of improved and innovative practices for water use in agriculture, specifically targeting three agro-ecological systems, namely: the irrigated, rainfed, and rangeland agro-ecological system.

USAID based the WLI on the concept that both the increased demands for freshwater from different sectors and the limited options for improving food and water supply in the region could have represented also an opportunity for change. Specifically, the recognition of the mutual need to husband and manage the water and land resources through greater engagement of stakeholders, while renewing human capital for future generations, represented the starting key concept to be piloted in specific benchmark sites of the seven participating countries. The establishment of effective partnerships among local, national and regional stakeholders, as well as the mutual enhancement of stakeholders' capacities through linkages with US university systems, has been one of the driving forces of the WLI. Particularly, five key US university systems Texas A&M University; University of California at Davis and at Riverside; University of Florida; University of Illinois at Urbana-Champaign, UIUC; and Utah State University participated in research cross-pollination and provided training exchanges with the local stakeholders; the educational and research strengths of the at the regional level the International Center for Agricultural Research in the Dry Areas ICARDA, the International Food and Policy Research Institute IFPRI, and the International Water Management Institute IWMI were involved into the design and implementation of project activities; and, finally, the knowledge and human capital existing at the national level coming from National Agricultural Research and Extension Systems NARES, regional universities, farmers, extension agents, students, NGOs, community-based organizations CBOs was leveraged and updated. Being USAID willing to establish a demand-driven project implementation strategy, the approach can be synthetized as it follows: the WLI forges partnerships in which NARES institutions define the needs, the Consultative Group on International Agricultural Research CGIAR Centers provide relevant research in the region and a platform in the Middle East, and Advanced Research Institutes ARIs help with the introduction of new ideas, technology and, in the case of universities, an opportunity to train a new generation of scientists that will be needed in the future.

Among the various lesson learned, thanks to the ongoing WLI experience, the importance of THREE key elements should be highlighted: i) transparent collaboration for project planning and implementation; ii) student and research exchange for capacity strengthening and building; and iii) employment of innovative ICTs to target project goals.

Transparent collaboration has been the trademark of the initial development stage, aimed at identifying the specific actions to be taken within WLI. This activity was conducted thanks to a two-year process of joint workshops coupled by online collaboration: a shared web-based wiki-like information system was established to facilitate the selection of appropriate project sites and the definition of effective actions to be taken in order to tackle representative water and livelihoods challenges of the region. The employment of a shared information exchange system boosted collaborative effort among stakeholders, helping to concretely define the WLI road map through the active editing of local proposals by the participants: by the end of the review period, the wiki reported over 800 visits to the website, further demonstrating the collaborative character of the WLI.

Student and research exchange at the benchmark sites started in 2011, thanks to the involvement of other programs and universities from both U.S. and the Middle East region. Specifically, WLI's partnering universities both U.S. based and regional, ICARDA, and IWMI played a significant role during the reporting period in launching the Student Exchange and Research Program by selecting students, identifying research topics, and by serving as advisors and co-advisors to selected student researchers. The adoption of summer exchanges was a successful cost-effective action for building and strengthening capacities, which was carried out also through specialized training offered to the NARES, *e.g.* on GIS Applications.

Innovative ICTs were employed in different stages of project implementation with the ultimate aim of targeting project goals. Not only ICTs were the subject of *ad hoc* training programmes to improve practices in the agri-environmental field, but trainees also benefited from a web-based closed group site that was especially set up for them to continue their discussions on the topic and learn from each other's experiences. In the case of GIS training module the trainees continued to collaboratively work towards developing land suitability criteria for their respective benchmark sites after the end of the training activities.

Moreover, information and knowledge exchange mechanisms were implemented to support transparent project planning and implementation, and these methods are likely to be employed to conduct participatory monitoring and evaluation of the WLI itself.

The way forward

A series of recommendations for the way forward can be drawn, basing on the elements analyzed in the previous sections.

- As stated by the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2008), *technologies such as high-yielding crop varieties, agrochemicals and mechanization have primarily benefited the better resourced groups in society and transnational corporations, rather than the most vulnerable ones. To ensure that technology supports development and sustainability goals, strong policy and institutional arrangements are needed*.... Just like research and development in agriculture in general, seed policies must be guided, not by a preconceived view about the benefits technology can bring to farming, but by a careful examination of their impacts on food security and, specifically, on the ability of the most vulnerable farmers to improve their livelihoods.
- The field of agricultural research requires a clear, non-reductionist approach that would not limit its vision to the provision of products or processes *silver bullets* originated by industries. The new approach is expected to review the linear model by applying the agro-ecology principles and techniques at different scales, from farm to the whole agri-food system, addressing also landscape-related agronomy issues.
- As a result, the international funding system of agricultural research for development should increase the share of resources dedicated to research programs and projects aimed at improving the whole agriculture and agri-food system (*e.g.* agro-ecology and agroforestry, soil management techniques, composting, water management, agronomic practices, drought resistant varieties or institutional strengthening), and with a particular attention to the community level (*e.g.* community seed banks, seed fairs and farmer field schools) rather than merely focusing on a specific trait of a single plant variety.
- Strategies in the public agricultural research sector should be based on a set of shared values that can distinguish between the needs of society and environment versus those of big business firms, as well as the interest of small farmers versus those of large international organizations that control the world markets. Moreover, policy makers will need to adequately support the shift of Agriculture towards a multi-functional sector that provides integrated externalities and ecosystem services without reducing the agricultural production potential of goods. Strengthen the inter-disciplinary attributes of innovation, as an integrated concept linking different scientific, policy and socio-economic fields. In this sense, innovation could lead to the improvement and conservation of local natural resources through participation of the agro-food systems' stakeholders, as well as strengthening full food sovereignty and guaranteeing that the results of public research could be systematically accessible thanks to open-source policies.

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