cirad
AGRICULTURAL RESEARCH FOR DEVELOPMENT

Agro-ecology for tropical and Mediterranean farming systems

CIRAD's research position

An essential transition for tropical and Mediterranean farming systems

The biophysical conditions in which tropical and Mediterranean agriculture is practised are notable for their contrasting climates (droughts or too much water), conditions which favour pest development, and poor, fragile soils. For a host of reasons it is often difficult to apply conventional intensification solutions in the poorest countries. These include rapid population growth, the withdrawal of the State, the influence of the globalized agro-industry, the lack of investment and inadequate services. Given these constraints, new transitions have to be found for tropical and Mediterranean farming systems if they are to meet the challenges of satisfying the food and economic needs of rural communities, promoting territorial development and preserving resources and ecosystems. Given this background, the various types of farming practised in the South need to innovate more rapidly but without reproducing the mistakes of productivist models. Sustainable production methods need to be developed which not only take into account constraints, but also make the most of opportunities: markets, resources and local expertise.

Under the influence of public policies, international donors and various interest groups, several agricultural and livestock production models co-exist within these changing regions. Of these models, agro-ecology is one of a family of diverse practices which share a common characteristic in that they use the ecological functions of agricultural systems to ensure sustainable production (we can also include conservation agriculture, organic farming, and permaculture in this family). These various systems, based on optimizing natural processes, are particularly suited to under-capitalized family farms, which are a priority research area for CIRAD. Moreover, family farms in the South have often developed highly elaborate local systems, such as agroforestry, which are a major source of inspiration for developing innovations that satisfy the demands of sustainable development. CIRAD has chosen to focus a major part of its research on studying how these agro-ecological systems function and assessing their capacity as credible alternatives to conventional production models.

As part of its research, which prioritizes southern regions and is conducted in partnership with local scientists and stakeholders, CIRAD is examining the biological, ecological and biophysical mechanisms which govern agro-ecological systems. In addition, it is studying the innovation processes and institutional regulations which need to be implemented with different actors in the design, adoption and dissemination of such innovative systems. Indeed, the many possible paths to agro-ecological transitions are not restricted to the biological, technical, economic, environmental, social and institutional aspects of farming systems. Making use of scientific and technical knowledge while taking into account

the key role played by farmers in innovation processes and of local situations and knowledge, and the training and capacity building of producers and coordination of local stakeholders are all essential preconditions for successful transition.

Understanding the mechanisms for biological and ecological regulation and better resource use efficiency within farming systems

> Ecological intensification as the main dynamic under study

Ecological intensification seeks to boost agricultural production and provide a range of ecosystem services by replacing, as far as possible, synthetic inputs – fossil fuels, fertilizers and pesticides – with the ecological functions of cultivated ecosystems. It is largely based on making use of functional biodiversity. The term "intensification" reflects the "intense" use of ecological processes as a major factor in production. While agro-ecology can be seen as a science, ecological intensification is an action science, a form of engineering, based on the knowledge generated by agro-ecology, ecology and agronomy, accompanied by the human and social sciences. It is this complementary path, which links knowledge production and the conditions for its use as part of an applied research approach that CIRAD is using in its research on agro-ecology and ecological intensification.

> Using functional biodiversity to improve natural regulation and resource use efficiency

CIRAD is focusing a major part of its research on understanding the ecological and biophysical regulation mechanisms linked to the use of functional biodiversity. One of the main aims is to improve the use of natural resources – light energy, water and nutrients – by optimizing biomass production and boosting the efficiency of bio-geochemical cycles, for example using intercrops, cover and service crops, rotations, etc. CIRAD is studying the distribution of the biomass produced in this context and the main carbon, water and nutrient fluxes between the soil, plants and the atmosphere at different organizational scales and using different cropping practices. In particular, the aim is to understand what determines how individual plants function within an agricultural system and the functional properties of cover plants under the effects of the environment and farmers' practices.

The second objective is to analyse and work on pest and disease regulation – a particularly important issue in tropical environments – through the appropriate use of biodiversity. To this end, CIRAD is studying the effects of the structure of plant and animal communities in farming systems on the nature and intensity of biological regulation processes, paying particular attention to the way in which trophic networks involved in these chains of interactions are reoriented. The dynamics of pests and biotic communities and the ecology and epidemiology of these pests, particularly in spatial terms, are being analysed. This work is also being fuelled by in-depth knowledge generated on host-pathogen relations, the evolutionary biology of populations, and the functional and trophic ecology of communities. The knowledge acquired is useful in developing dynamic models of pest and disease development to support the definition of integrated crop and herd protection and pesticide reduction strategies. It also serves to develop more general models of agrosystem functioning (from the plant to the landscape scale), which helps identify the factors that govern how agrosystems and associated ecosystem services function.

> Renewing crop genetic improvement objectives and making use of intra-specific biodiversity

Agro-ecological transitions bring new challenges for varietal innovation. First and foremost, optimizing biological interactions means exploring the possible links between the mechanisms which can be used as part of an ecological intensification approach and their potential expression at the level of the genome. Implementing solutions based on agro-ecological principles also means putting varietal solutions into context, in other words integrating them into the local realities of production systems, crop rotations and intercropping schemes. This additional complexity has prompted CIRAD to broaden the scope of its objectives and breeding criteria, and integrate local knowledge into breeding strategies. The speed and diversity of the ecological, technical and economic changes under way have also raised new questions about the varietal deployment strategy for each species.

CIRAD, which has been working for decades to improve tropical species, is using new genomics tools to tackle these challenges. While these tools enable rapid progress in terms of knowledge generation, the fact that agro-ecology takes greater account of biological interactions raises a uniquely complex set of questions. For example, the conventional approach, which involves analysing genotype and environmental interactions, has now reached its limits, due to the diversity of local situations and the exponential growth in the number of possible genotype combinations. As a result, CIRAD is looking into new ways of managing genetic diversity, notably through participatory breeding methods (decentralized dissemination, open-access varietal formulas, multi-genotype breeding, local "refining" of varieties, etc). It is also helping to diversify seed and plant propagation methods.

In addition to the scientific challenges, there is also the issue of what type of innovation model to promote, since plant breeding is also an economic undertaking. Seed sector regulations and the fact that varietal innovation is concentrated in the hands of a small number of powerful global players are often incompatible with agro-ecological transitions, which require the involvement of a range of stakeholders.

Similar questions also apply to the genetic improvement of livestock and, looking further forward, to all of the various innovations likely to occur in terms of micro-organisms. In this context, the legitimate intellectual property rights of each of the stakeholders involved is difficult to pinpoint but, in any event, the rights of communities in agro-biodiversity must be recognized if agro-ecological transitions are to be successful.

The design and multi-criteria and multi-scale assessment of production systems founded on the principles of agro-ecology

> A renewed farming system design approach

CIRAD is working to design new tropical and Mediterranean farming systems in a wide range of agricultural contexts (small-scale family farming, peri-urban horticulture, agroforestry, monoculture systems undergoing conversion, etc). Designing such agro-ecology-based systems means using a range of new technical levers in order to optimize the management of biological diversity and the associated regulation mechanisms.

More appropriate land use fosters the capture of natural resources (intercrops or catch crops, agroforestry systems, multi-species systems, etc). The spatial and temporal organization of crops within a farming system serves to boost natural regulation processes. Maintaining and improving soil fertility requires the use of service plants with nutrition, facilitation and regulation functions (permanent plant cover) and exploiting the complementarity between crop and livestock farming operations. Developing small-scale mechanization in order to make farmers' work less taxing and to offset crop sequences which are potentially more labour-intensive are also key elements to be taken into account when developing innovative systems based on agro-ecological principles.

> The capacity for multi-criteria and multi-scale assessments of system performance is essential

Innovative agro-ecological systems are based on finding compromises in terms of performance and resource management. Designing "multi-service" systems means pinpointing optimum combinations, specific to each location, bringing together compromises and synergies between services. The amount of time required to switch from a conventional to an agro-ecological system also needs to be taken into account. Assessing these services scientifically is also a determining factor in facilitating their acceptance by society.

When designing innovative systems, it is vital to ensure their performance can be assessed at various organizational scales. Levers for designing new systems can be found at the farm level, at the landscape level (installing hedges, refuges or wooded parks, managing fertility transfers and interactions between crop and livestock farming) and at the territorial level, where producers have to negotiate land use and the sharing of resources with other actors, either individually or collectively. To this end, combining models for agrosystem functioning with decision support models should be encouraged, alongside the definition of indicators which can be interpreted at the different organizational scales.

Studying and facilitating innovation systems to support agro-ecological transition

The technical changes involved in agro-ecology inevitably bring changes in food, social, economic, institutional and political systems. Producers integrate their decisions to change into a complex set of dynamics and strategies aimed at boosting their income or food security. CIRAD is therefore studying and supporting agro-ecological transitions within the broader framework of its studies on agricultural transitions at several organizational levels: farm, territory, rural organizations, countries and regions. For agriculture in tropical and Mediterranean areas, where innovation and research systems are often still under construction, such studies combine diagnoses, knowledge generation, capacity building, and supporting innovation processes and, more broadly, underlying institutional dynamics.

> Documenting and taking into account the diversity of local contexts

Agro-ecological transition pathways are strongly dependent on local production conditions and their socioeconomic or institutional environment. Facilitating transition requires an understanding of the constraints, risks, assets and opportunities it brings and giving a central role to innovation processes and to farmers. CIRAD is therefore conducting regional diagnoses of a wide range of production systems and environmental and social conditions. Farmers' strategies and the local knowledge on which they are based are research topics in their own right. These diagnoses then serve to identify levers at various organizational scales which will facilitate a transition to agro-ecology.

> Taking into account how supply chains and markets function

While most family farms have links with markets, the economic environment is not always favourable for agro-ecological innovations. Conversely, these innovations are not always suited to the quality and logistical standards that prevail in various markets (international, domestic) and to consumer demands in terms of product quality, quantity, consistency and accessibility. Research is under way to determine how producers can boost their share of the added value generated in growing niche markets (organic farming, natural products, etc) and conventional markets. Cutting marketing and transaction costs for products which are often more qualitatively heterogeneous than industrial goods is a lever for agro-ecological transition. CIRAD is conducting complementary studies on how supply chains are organized, changes in standards and the emergence of new marketing methods for more sustainable farming and food systems that better satisfy the needs of producers, consumers and society as a whole.

> Developing collective learning tools

Generating, sharing and using knowledge, information, know-how and learning are essential for dynamic rural areas, and are particularly important for supporting agro-ecological transitions. These transitions involve individual and collective pathways which are often highly specific and differentiated, within which learning, knowledge and the sharing of experiences, the circulation of information and the capacity to apply scientific knowledge play a key role. CIRAD uses various knowledge engineering methods to facilitate participatory and collaborative learning (primary data gathering, participative technico-economic zoning and models, local and expert knowledge, smallholder trials, change simulation, etc), which all serve as decision support and negotiating tools for helping local actors change their production systems. These methods differ from those previously used for the dissemination of innovations in that they take into account local specificities and differentiate between situations and the appropriate solutions.

> Developing collective action, support structures and informing public policy for agro-ecological transition

Whether the transition is prompted or spontaneous, producers proceed with uncertainty, through experimentation and through exchanges with their peers and with experts. They can be supported in various ways, from individual advice to workshops on participatory design involving farmers, experts, technicians and researchers. CIRAD supports the professional bodies involved in agro-ecological innovation processes, participating in the design, implementation and evaluation of local and regional innovation platforms. On the territorial scale, it is involved in collective and public actions designed to

better integrate agro-ecological transitions and sustainable resource management.

These various approaches serve to foster the exchange of local and scientific knowledge and fuel the debate on practices and regulatory mechanisms. They are an integral part of the capacity to innovate in Southern societies, which will enable these populations to address development issues. They serve to inform and contribute to public policy which, in return, may be adapted in order to encourage and support more effectively agro-ecological transitions.

Agro-ecology and climate-smart agriculture

Within a given local context, agro-ecology makes use of all the functions of ecosystems in order to cut fossil fuel use and reduce negative environmental impacts, paying particular attention to the circulation and efficiency of biogeochemical cycles. In this respect, agro-ecology is a form of climate-smart agriculture, an approach that promises to offer simultaneously adaptation to climate change, mitigation of this change, and sustainable production. However, the various forms of climate-smart agriculture and the different levers this type of agriculture may employ are not all compatible with agro-ecological principles. Climate-smart agriculture often claims as its main priority adaptation to and mitigation of climate change and, as such, may require inputs and techniques not used in agro-ecological practices. The list of differences also includes the fact that the scientific bases underlying the two approaches have not been developed to anything like the same extent: scientific agro-ecology bases its principles on ecology and agronomy and has been covered by numerous research studies, while climate-smart agriculture is a very recent concept as yet backed by very little research. Nevertheless, these two visions of agriculture face a set of shared challenges, for example the importance of building knowledge on soil functioning and its capacity to sequestrate carbon, the need to take into account the territorial level and local social dynamics when organizing production systems, and the development of multi-criteria methods for assessing production system performance so as to evaluate the different services rendered.

Continuing research on agro-ecology: towards “intelligent territories”?

By studying eco- and biophysical processes and producer practices, and studying and supporting agro-ecological innovation processes, CIRAD has developed unique knowledge and operational solutions in the field of agro-ecology. CIRAD’s research experience clearly shows the necessity of continuing to build our basic knowledge of how agro-ecosystems in the South function. It also demonstrates the lack of a “universal” solution for developing innovative systems, and the importance of involving various categories of stakeholders in order to speed up agro-ecological transitions at the territorial scale. The biophysical and agronomic dimensions as well as the social, economic, institutional and technological aspects of these territories must be understood, since it is this knowledge that makes it possible to pinpoint the range of constraints, risks, assets and opportunities against which agricultural production and, more broadly, agricultural and food systems must evolve. Their mode of governance is a key factor in these transformations. In this context, research has to promote the concept of “intelligent territories”, which combine knowledge engineering and the use of information technologies, capacity building, evaluation of public policies and the building of territorial observatories. It must also strengthen its capacity to link specific innovations tailored to local contexts and generic knowledge to generate transformations at significant scales.

Contacts

F. Côte & E. Hainzelin
CIRAD

francois.cote@cirad.fr

etienne.hainzelin@cirad.fr