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▲ *Participatory assessment of problems encountered (low biomass, inefficient erosion control, poor planting, etc.) on a DMC plot in the Brazilian Amazon region.*

▶ *Installation of BROCAP® bark beetle traps.*

▼ *Weevil trap in a banana plantation, Martinique.*

Developing and *disseminating innovations*

R. Domergue © CIRAD

In many situations, research and development stakeholders complain that farmers take little advantage of innovations developed by researchers in laboratories or research stations. There are several reasons for this nonadoption, which have been the focus of numerous intra- and inter-disciplinary studies for several decades. These studies have given rise to 'farming systems research' approaches, which stress the importance of identifying and understanding farmers' rationales, strategies and practices prior to or at the same time as developing innovations for—and sometimes in collaboration with—farmers.

Many current projects are aimed at developing tools to support farmers in redesigning their production systems, while others seek to identify and assess public or private support measures that would be more efficient in creating an environment that is more conducive to the transformation of these systems. Modelling and simulation have a major role, even within stakeholders' groups for negotiating types of changes to promote and ways to induce them.

In these studies, agronomists are involved to an increasing extent: (i) to assess, within research units, invention and innovation development processes, and to improve design approaches and the type of technical references produced, (ii) with development and extension services, to study how stakeholders-experts responsible for disseminating knowledge are involved and communicate on available technical alternatives, (iii) to study how it would be possible to combine the knowledge of scientific experts and farmers so as to invent new systems that would be more readily adopted, and (iv) to introduce new 'farming system research' approaches by taking the multiple activities of farm households and risk (climatic, market, etc.) management into much greater account. This work complements that of other disciplines (especially social and economic) on the question of the adoptability of innovations by farmers. They also help to change researchers' approaches, to take the opinions of stakeholders other than public and private farmers into consideration in the analysis of processes, as well as everyone's perception of their occupations and combined activities.

Jean-Marc Barbier (UMR Innovation)

R. Domergue © CIRAD

Developing and *disseminating innovations*

Research teams

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Study of individual *and collective* innovation processes

The **joint research unit (UMR)** ***Innovation and Development in Agriculture and the Agrifoods Sector*** **(CIRAD, INRA Montpellier SupAgro)** conducts multidisciplinary research in France and internationally on individual and collective innovation processes, i.e. technical, organizational and institutional.

The research is focused on all processes, ranging from stakeholders' innovation motivations and objectives, practical ways for implementing change to the impacts of development induced by these innovations. The UMR combines expertise in agronomy and social sciences.

The UMR studies 'situated innovation' by approaching innovation via the analysis of 'under way' action processes in different settings, change situations, and different issues (specific agricultural techniques, alternative agricultures, etc.). It should be possible to generate information and knowledge on overall patterns by placing these situations in perspective. The researchers adhere to partnership action research principles and participate in changing action objectives and those of all stakeholders involved.

The UMR is organized in three teams:

- **'Technical and Organizational Changes in Agricultural Production Systems' (SPACTO):** focused on the analysis of technical and organizational change on farms
- **'Social Construction of Markets, Qualities and Territorial Development' (MARQUALTER):** analyses changes in products and markets
- **'Territorial Innovation' (IT):** focuses on the analysis of territorial dynamics and impacts on agriculture, especially in urban and periurban situations.

Research on cropping systems and agricultural production is mainly conducted by the SPACTO team, with the aim of strengthening the adaptation capacities of family farms to changes in their environment (market and environmental constraints). This is addressed by descriptive and analytical approaches and through support facilities in which modelling and simulation tools are essential.

This multidisciplinary team (agronomists, economists, sociologists) is organized along three lines:

- analysis in changes in agricultural production systems and rural household activity systems, and support in the design of innovative technical systems on the farm scale

▲ *Direct seeding of maize on harvest residue mulch in small-scale mechanized farming conditions. Xayaboury province, Laos.*

F. Julien © AgriDev

DMC adoption in developing countries

DMC techniques have mainly been adopted over the last three decades in South and North America and Australia, where they have emerged independently from national research and extension systems. These technical changes are harder to implement in developing countries because of the nature of most of their agricultural enterprises: small farms, subsistence strategies, limited risk-taking, limited resources, and the role of community exchanges. In these situations, the strategy should thus be to enhance potential adopters' access to other forms of capital (land, financial, human/social) in addition to technical capital, along with interventions in the spatial and economic environment of farms—land management and commodity chains.

The example of Alaotra Lake, the main area of DMC adoption in Madagascar, is interesting for several reasons. Almost 1 500 farmers are currently implementing DMC in an area of 1 200 ha. The adopted systems incorporate local crops at different intensification levels, which can be adjusted according to farmers' capacities and objectives. Farmers' organizations are structured and have gradually been interacting with different stakeholders involved in agricultural production: microfinance institutions, banks, private operators, decentralized local authorities, and NGOs. In Laos, family farms differ by the fact that they are closely connected to the private sector —especially marketing and service supply companies. Because of this specific feature, a short-term development approach, combining regional/territorial with commodity chains levels, is possible. In the province of Xayabouri, where there is high pressure on natural resources (increased demand for raw materials from Thai agroindustries), over 1 600 farms currently implement DMC in a total area of around 2 000 ha.

Innovation processes observed in these two settings are specific responses to farmers' 'risk management' strategies. They indicate that it is possible, with a tailored method, to foster sustainable adoption of DMCs on low-resource family farms.

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■ *ex-ante* assessment of territorial consequences of individual changes, and analysis of relationships between farms and stakeholders involved at different global organization levels (catchments, etc.)
■ evaluation and development of farm advice and support systems and methods.

Three research issues are investigated: production management and choices of combinations of activities (agricultural or not) on farms; sociotechnical production method transformation processes; and stakeholder coordination processes.

The research is conducted in several areas:
■ France: viticulture (Languedoc-Roussillon) and rice-based cereal cropping systems (Camargue)
■ West Africa (Madagascar), North Africa and Brazil: rice cropping systems and mixed cropping-livestock systems (especially dairy production)
■ African cotton-growing regions: agropastoral systems
■ humid tropics (Africa and Central America): agroforestry systems.

SPACTO places emphasis on certain types of innovation: (i) conservation agriculture (France, Brazil), integrated protection (viticulture, France) and organic agriculture (grapevine and cereals, France); (ii) enhancement of crop-livestock relationships on farm and territorial scales (Brazil, West Africa, Madagascar), (iii) and species associations (agroforestry in Africa and Central America, grapevine and cereals in France).

The team collaborates with farmers and farmers' organizations, research and teaching teams in industrialized and developing countries, development institutions, private operators, NGOs and donors. •••

Organic viticulture–integrated analysis of the conversion to organic agriculture

▲ *Vineyard in the process of conversion to organic agriculture.*

© A. Mérot

Organic agriculture (OA) is an ideal framework for setting up more sustainable cropping systems, especially for viticultural systems in which pesticide treatments are substantially used. OA conversions are occurring at a fast pace in viticulture, especially in Mediterranean vineyards (+ 20% between 2006 and 2008 according to Agence Bio) even though the knowledge and tools required to analyse, predict and support this change are not yet operational. Demand is currently high from farmers and extension agents, as well as companies and cooperatives. To fill this gap, the hypothesis was put forward that an integrated approach to the biophysical, technical, socioeconomic and organizational dynamics involved in the OA conversion phase (before, during the 3 year regulatory period, and after) could enhance the sustainability of this innovation.

The development of such an approach is based on conceptual modelling of viticultural systems in the process of being converted to OA, with the aim of formalizing scientific and expert knowledge on viticultural systems. The approach requires on one side to identify relevant indicators for monitoring the OA conversion process. Moreover, it involves modelling the functioning of a viticultural system during the conversion phase with respect to the dynamics of the biophysical processes (plot scale) and the technical and decision dynamics (farm scale). The expected results are in four areas: i) enhanced understanding of the OA conversion process, ii) identification of analysis and conversion management indicators and implementation of a formal systems analysis approach to viticultural systems, iii) setting up a network of OA viticultural farms and plots for long-term monitoring of the conversion impact, and iv) the formalization of knowledge required for drawing up guideline sheets and professional training to support conversion to OA.

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Designing cropping *systems that combine* economic performance *and preservation of* natural resources *and the environment*

The joint research unit (UMR) *Tropical and Mediterranean Cropping System Functioning and Management* (SYSTEM, CIRAD, INRA, Montpellier SupAgro) focuses on agronomic aspects of cropping systems. It produces knowledge and tools for assessing and designing cropping systems that combine economic performance and preservation of natural resources and the environment. Emphasis is placed especially on the use of biological diversity of crop species and management of crop associations in order to achieve steady agricultural performance (yield and quality) under socially acceptable conditions, while reducing environmental impacts and natural resource use.

The main hypothesis tested is that the crop association structure and management method can be designed—on plot, farm or territorial scales—for multifunctional and multispecies systems.

The research is focused mainly on associations of perennial plants with productive functions (fruit, wood) and 'service' species, aiming at optimize the system performance with limited input use. The reference cropping systems are:

- forestry-arable crop systems (row crops, mechanization, with trees and grain or forage crops)
- coffee cropping systems with shade tree cover
- viticultural systems with row intercropping
- agroforestry systems with coffee and cocoa.

The unit is organized around two teams:

- **The 'Analysis and modelling of multi-species cultivated field' (AMPLUS)** team generates knowledge on the biophysical functioning of multispecies crop fields with the aim of optimizing their structure and management, while emphasizing multifunctionality under climatic and production system constraints.

Research teams

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■ **The 'Design of cropping systems' (CONSYST)** team develops methods for assessing existing systems and designing new ones on the basis of the agroecological principles presented above, in given socioeconomic and biophysical contexts.

These teams work with a technical and engineering team ('Cropping systems, modelling, experimentation') to produce indicators, models and tools, in partnership with development organizations and companies.

In temperate agroforestry conditions, agroforestry plots located in a station for long-term experimental studies (Vézénobres, Restinclières, France) are compared with agricultural and forestry control plots. In this work, the unit supervises other research and development teams.

In integrated viticultural systems, cropping systems that provide environmental services are tested at the *Domaine du Chapitre* (Hérault, France). A long-term experiment on low-input cropping systems will be set up in collaboration with the Domaine viticole de l'INRA (Bordeaux, France) and development partners *(Institut Français de la Vigne et du Vin,* inter-branch professions).

For tropical agroforestry systems (farmers' and experimental plots in Costa Rica and Cameroon), the research platform in partnership (PCP) Agroforestry Systems with Perennial Crops in Costa Rica has formalized relations with the *Centro Agronómico Tropical de Investigación y Enseñanza* and various Central American institutions. The PCP *'Grand Sud Cameroun'* associates several CIRAD research units with the *Institut de Recherche Agricole pour le Développement*, and the *Universités de Dschang et de Yaoundé 1*.

The *Association Française d'Agroforesterie* is the unit's major link with agricultural development for field transfer of research knowledge. The UMR also benefits from the Montpellier research network based project 'Towards a federative research on modelling and simulation platforms' and that of the Record project to facilitate exchanges within an international network on the integrated modelling of agricultural systems. Moreover, a European partnership initiated by the unit as part of the Seamless project (integrated assessment of agricultural systems) is now firmly established in an association with the same name, which will provide a framework for new initiatives with the Universities of Wageningen and Bonn. ■

Sustainable production and innovation for smallholders in developing countries

The improvement and stabilization of smallholders' agricultural production are key challenges for international agronomic research. Soils in tropical environments are varied but fragile and the climatic conditions are harsh, with a high probability of catastrophic events occurring. Socioeconomic conditions for smallholders in such regions are also often difficult and volatile, with limited access to markets and credit. In such conditions, innovative systems proposed should preserve and make efficient use of available natural resources in the short- and long-term, maintain or even increase productivity, while limiting the environmental impacts of agricultural activities. CIRAD, along with its partners in industrialized and developing countries, is thus involved in a process to develop/assess direct seeding mulch-based cropping systems (DMC) adapted to tropical conditions.

These systems are based on no tillage, permanent plant cover, diversified rotations and the use of multifunctional cover crops. They have proved effective in stabilizing grain production (better water and nutrient use) and in enhancing certain ecosystem services (erosion control, carbon storage, soil biology, etc.). Modelling on plot and farm scales helps to accurately characterize the complex functioning of these systems and to assess their potential integration in production systems. A participatory process for the co-development of these innovative cropping systems is currently being implemented in different countries to promote their dissemination. It involves many exchanges between researchers in different disciplines, technicians and the different types of producers concerned, thereby contributing greatly to the reciprocal learning process necessary for everyone and gradually familiarizing farmers with DMC.


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▲ *Bean crop under DMC in Madagascar.*

Anti-insect netting tailored for protecting vegetable crops in the tropics

© T. Martin

▲ *M. Tonou, a horticulture farmer at Ouidha, Benin, explaining to his colleagues how to use anti-insect netting to protect cabbage crops.*

In tropical regions, vegetable crops are infested year-round by a broad range of pests. Farmers generally deal with this problem by spraying pesticides. Although farmers, through such unplanned and uncontrolled chemical treatments, may sometimes be able to turn a profit, the residues remaining on the vegetables are a threat to consumer health, and there is a high groundwater pollution risk. It is now crucial to develop alternative pest management methods that are less dependent on chemical inputs. In Benin, the mosquito netting principle was adapted for the protection of cabbage crops—plastic netting placed over the crop late in the day thus kept pests (mainly nocturnal) from reaching the plants to feed and lay their eggs.

This economically viable and sustainable technique, which is also easy for horticultural farmers to understand and implement, reduced the number of pesticide treatments by tenfold, while increasing production. Physical control is proving well suited to small farms that employ family labour. This technology was developed through a participatory approach involving all stakeholders in this commodity chain. The physical control conditions and concomitant modifications in cropping practices have been defined within the framework of a prototyping initiative that takes cropping system constraints identified during a preliminary assessment into account. Extension of the use of anti-insect netting for agricultural applications also provides an opportunity to recycle mosquito netting used in malaria control programmes. Moreover, the use of anti-insect netting will be studied for other vegetable crops such as tomato and leafy vegetables, while also combining this technique with other alternative pest and disease control methods.

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Innovation and supporting mixed cropping-livestock farms (Burkina Faso)

In sub-Saharan savanna areas, the extension of technical innovations in different production sectors has shown its limits. It cannot, for instance, provide a solution to complex issues such as soil fertility management, crop-livestock integration, or changes in cropping patterns on farms.

In cotton-growing areas in Burkina Faso, CIRAD has developed tools and a support strategy to help farmers change their production systems. This involves assisting farmers in developing innovative cropping systems that are cost-effective, socially acceptable, more efficient in capitalizing on input investments (fertilizer, concentrated livestock feed) and ecological processes (recycling of grassy biomass). This research is based on previously acquired technical results and farmers' knowledge and know-how. Possibilities of adoption and adaptation of these systems are evaluated jointly with farmers.

In addition to the work carried out with farmers, mixed crop-livestock farm functioning models are developed, which stimulate discussions with farmers on the best and most effective changes that they would like to make on their farms.

These tools enable farmers, as well as extension agents, to assess different production unit changes in terms of income and food security, the soil fertility balance or the forage balance on different livestock production farms. They can, for instance, be used to assess the feasibility and impact of including a forage crop in a rotation or of increasing the number of animals to fatten.

These computer tools will ultimately be implemented by advisors to help farmers in making strategic decisions (choice of activities, design of production areas, planning of technical interventions). This approach has also been developed in partnership with farmers and development organizations in other mixed crop-livestock farming situations in Brazil and Madagascar.

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▶ *Mechanical weeding in a cotton field—cattle draught is still an essential element for crop-livestock integration in Burkina Faso.*

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