Sustaining conservation agriculture: lessons learned from the EU project KASSA

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The questioning of the sustainability of conventional plough-based agriculture led to the emergence of alternative concepts and practices such as conservation agriculture (CA), which is currently spreading in many places. CA-based systems are said to rely on the simultaneous use of three main components: (1) reduced tillage or no-tillage and direct seeding for less disturbance of the soil and proper crop establishment; (2) soil cover to mitigate erosion, reduce weeds, and improve soil fertility and functions; and (3) crop rotation to control pests and diseases. These systems are thought to respond to production-protection requirements; interest in their applicability and results is growing.

Knowledge Assessment and Sharing on Sustainable Agriculture (KASSA) is an EU-funded project that intended to extract lessons from past research on CA. It did it through a step-by-step and iterative process that took place within four regional platforms: Asia, Europe, Latin America, and the Mediterranean.

In the four platforms of KASSA, implementation of the concept of CA gave rise to many farming practices. The no-till–based systems are the most common: in some places, they are about to replace completely the conventional plough-based systems. However, soil cover and sound crop rotation are still hardly practiced because of biophysical conditions; low biomass production; competition from livestock; lack of adapted varieties, of implements, and of knowledge; and general market conditions. The absence of these components makes the systems rely mainly on using chemicals to control weeds, pests, and diseases.

The reduction in production costs CA systems provide often acts as a powerful argument for their introduction and adoption. But this argument alone is risky because (1) the development and fine-tuning of these systems is knowledge-consuming and (2) their suitability and efficiency are highly sensitive to local biophysical, social, cultural, technological, institutional, market, and policy environments. Furthermore, there are relatively few scientific data on CA systems; particularly, their long-term agronomic, environmental, and socioeconomic impacts are still not well understood.

Substantial systemic and multidisciplinary research effort is needed to understand the functioning of CA systems and their socioeconomic and ecological sustainability conditions.

Keywords: Conservation agriculture, drivers, constraints, impacts, knowledge, sustainability.

Conservation agriculture (CA) refers to the simultaneous use of three main principles: (1) less disturbance of the soil, that is, reduced tillage (RT) or (NT) no-tillage and direct seeding; (2) soil cover, that is, crop residue, cover crops, relay crops, or intercrops to mitigate soil erosion, reduce weeds, and improve soil fertility and soil functions; and (3) crop rotation to control pests and diseases. Other terms such as conservation tillage (CT), zero-tillage (ZT), and direct drilling (DD), and direct sowing/seeding (DS) apply to CA.

CA emerged historically as a response to soil erosion crises in the United States, Brazil, Argentina, and Australia. According to available data, CA currently spans over almost 100 million hectares worldwide.

The Knowledge Assessment and Sharing on Sustainable Agriculture (KASSA) project aimed at taking stock of past research results on sustainable agriculture (http://kassa.cirad.fr). It was funded by the European Commission within the 6th framework research program.

In the agroecological and socioeconomic environments considered in KASSA, CA is practiced in several ways. For many reasons, the basic trilogy of CA is not always fully respected, which may lead to declining performance of CA systems or even making them underperform in some sustainability aspects. This paper deals with the practices and adoption of CA in KASSA platforms and their reasons. It emphasizes knowledge gaps that deserve more research and development actions in order to help ensure CA sustainability.

The KASSA project

KASSA is a worldwide initiative assembling 28 partners from 18 countries in Europe, North Africa, Southeast Asia, and Latin America.

KASSA focused mainly on conservation agriculture; it worked simultaneously within four regional platforms: Europe, the Mediterranean, Latin America, and Asia. The project was implemented through a step-by-step and iterative process. This process began with the development of comprehensive inventories and assessments of existing and validated knowledge on sustainable agriculture in the four different regional platforms. It continued with a comparative critical analysis across the platforms, then refined the findings, and concluded with a final synthesis. Reports released at each step were submitted to the critical review of a panel of experts. A closing conference addressed the prospects for CA in the regions considered by KASSA.

Practices and adoption of CA in KASSA platforms

European platform

The introduction of CA practices in Europe in the early 1960s was mainly driven by economic considerations (Soane and Ball 1998)[1]. Farmers in the UK and Scandinavia seem to have been among the first adopters of CA practices. In the UK, by 1978, 8–10% of the winter cereals were grown under NT or RT; however, by 1990, there was a strong move of farmers back to mouldboard ploughing because of several unforeseen problems of weed and crop residue management (Soane and Ball 1998). The same scenario

[1] In this text are cited only additional references, that is, ones not used in KASSA and not referenced in the KASSA database.

occurred in Scandinavia between the 1970s and late 1990s (Rasmussen 1999); the reasons given were residue management problems, grassy weed infestations, and excessive topsoil compaction (Munkholm et al 2003). According to Håkansson (1994), in Scandinavian areas where CA practices had been advocated without having previously carefully investigated all consequences, farmers who had started using these methods sometimes returned to traditional methods. In erosion-risk area in Norway, there is a clear tendency of shifting from RT with no ploughing to spring ploughing. In France, farmers' interest in CA began in the 1970s, mainly driven by the need to reduce labor time, but, in the 1980s, this interest decreased because of favorable economic conditions and the higher costs of herbicides. By the 1990s, the Common Agricultural Policy (CAP) reform and international market conditions led farmers to again seek to reduce production costs and improve productivity. This new interest in CA was helped by the availability of adapted implements and a decrease in herbicide prices. Hence, experience with CA in northern Europe varies from country to country and from region to region within a country; farmers' interest in CA systems also varies with time.

In Eastern European countries, many research trials were carried out in the last decade (Javůrek and Vach 2006, Martyniuk et al 2006, Dryšlová et al 2006, Smutný et al 2006, Winkler and Smutný 2006); farmers' interest in CA practices is just beginning. In the Baltic countries, some long-term experiments seem to have begun in the late 1980s (Jodaugiene et al 2006); farmers' adoption of CA practices is not yet clear.

Data on CA extension in the European platform are scarce at the EU or country level and may not apply to the whole cropping system. Figures assembled tend to ascertain that CA practices are less adopted in Europe and that RT is more common than NT. Most of the areas listed as NT may correspond to fields managed in NT only for a part of the rotation, whereas the other crops of the rotation are managed using RT or ploughing (Lahmar et al 2006).

The Mediterranean platform

Spain seems to be the country of the platform with the strongest experience in CA. The interest in reducing labor time rose in the 1960s, but CA principles were introduced in the 1970s only, mainly through knowledge from the U.S. and later from Australia. The real development of CA practices began by the 1980s with the involvement of technical advisers from agricultural services, farmers' cooperatives, and multinational and national companies and scientists as well as the support provided to some regions. Eleven farmers' societies and consortia have been created across the country; they played a key role in the development and adoption of CA by farmers. The Spanish Conservation Tillage Research Network created in 1996 identified, between 1996 and 1998, 22 research groups across Spanish territory collaborating with farmer-adopters of CA and developing basic and applied research linked to farmers' concerns, including long-term experiments to assess and develop CA systems. The shift from plough-based systems to CA systems took place through two steps. The first step was the widespread adoption of RT techniques; the second step, ongoing but to a lesser extent, is the adoption of NT with more than 30% of the crop residue left on the soil surface. The adoption of NT practices faces many problems linked to soil compaction; straw and stubble management; higher incidence of weeds, pests, mice, rodents, slugs, and diseases; and a lack of knowledge and technical advice, which sometimes discourages farmers. Actual data on the expansion of CA in

Spain are not available.

In Italy, no-tillage trials started in 1968, but CA expansion began only in the 1990s; it was driven by the need to reduce crop costs and helped by the availability on the Italian market of sowing equipment and adequate herbicides (De Vita et al 2006).

In Morocco, research on CA systems in rainfed dryland wheat-fallow–based agriculture started in the 1980s. Many published results show that CA improves yields and profitability of rainfed wheat systems and soil water, carbon, and fertility, and reduces soil erosion and production costs. A prototype driller has been developed. But, farmers' adoption of CA in Morocco remains incipient (Lahmar 2006).

The Latin American platform

Latin America is the region where the CA concept has been shaped and is currently practiced on about 45 million hectares. According to available data, Brazil and Argentina total near 45% of the world's surface cultivated under NT.

The most famous success story is that of Brazil, where farmers began no-till as a response to soil erosion. The innovation process started from the subtropical region, led mainly by large-scale farmers. The availability of planting equipment and suitable herbicides is one of the main technical factors that contributed to the dissemination of CA in the country. Nowadays, the proportion of cropped area under CA in subtropical and tropical Brazil is nearly the same: respectively, 55.6% and 44.4%. However, despite the availability of a wide range of equipment—hand-operated, animal-drawn, and motorized—for cover crop/crop residue management, planting, and spraying, CA adoption by small-scale farmers occurred only in the subtropical region.

According to farmers' views, CA adoption by large-scale farmers was mainly driven by cost savings in the use of machinery. A reduction in labor requirements and drudgery was the major driving force for CA adoption by small-scale farmers. The main constraints to CA adoption by small-scale farmers are difficulties in weed control and lack of knowledge on herbicides and their use, increased incidence of pests, and a higher use of pesticides.

A survey of CA adoption in the state of Paraná showed that family farms incorporate tillage operations into their NT systems according to the opportunities and constraints they face, that is, weed infestations and soil compaction, which are seen by farmers to increase with time; input costs; availability of labor; and knowledge on herbicides. Despite the efforts made by research and extension in promoting diversification of cover crop species and rotations, most family farmers still use a limited range of species and practice rotations with the same crops, repeated in successive cycles. This is likely linked to the attitude of farmers toward risks and may demonstrate that cover crops and diversified crop rotations are not used if they do not provide a short-term economic benefit.

Regarding soil erosion, empirical observations of the drastic reduction in soil erosion by NT practices in Brazil led to a general thought that NT systems by themselves were strong enough to control erosion. Consequently, farmers neglected complementary conservation practices and eliminated terracing systems. Recent results showed that protection of the soil surface by crop residues in NT systems is not always followed by a reduction in runoff. In addition to leaching of nutrients and pesticides, sheet and rill erosion developed even at sites where NT systems have been used. A new conservation technique, called “*vertical mulching,*” is being developed in southern Brazil in NT systems.

In Argentina, the NT adoption process started during the 1970s with some small-scale trials. During the 1980s, adoption started to spread. Nowadays, around 65% of the total country farmed area is being NT-cropped and a large NT area is located in the central area of the country. CA development and dissemination in Argentina have been mostly led by farmers and their organizations. Farmers practicing large-scale market-oriented agriculture played a key role in the process. Cooperation between farmers and industry allowed developing appropriate drillers and planters that helped in the propagation of CA. During the last decades, Argentinean agriculture had undergone a deep transformation with a strong adoption of NT and biotechnology. Now, around 65% of the total grain and oilseed production is coming from “*new farmers*” that produce on rented land and contract for different services to raise and harvest crops. This new agriculture is seen as modern sustainable high-productivity agriculture. Constraints to the development of CA in Argentina are not known.

In Bolivia, the development of CA-based technologies started in the 1980s as an initiative of farmers from the eastern lowlands without any support from research institutions. In 1993, through cooperation between a farmers’ society and CIMMYT, NT started as a tool to improve the profitability of the soybean-wheat rotation. Thereafter, two specialized no-till networks linking public research institutions, farmers’ societies, and agrochemical companies emerged.

NT and RT are still incipient in the Andean valleys where small-scale intensive farming predominates. A cover crop is difficult to establish, crop residues are sold or used to feed livestock, and farmers lack capital to invest in machinery. In the humid tropics, CA is practiced mainly for annual crops. Driving forces for large-scale farmers have been savings mainly in diesel consumption and the possibility to extend the planting period from about 3 days after the first rains to about 12 days. The main constraints to CA adoption by small and medium-scale farmers seem to be the lack of machinery and cultural or religious beliefs. The low use of cover crops and crop rotations resulted in soil compaction and crusting problems; the maintenance of a soil cover itself poses problems in the humid tropics due to the rapid degradation of the biomass.

The Asian platform

In the Indo-Gangetic Plains (IGP), rice-wheat (R-W)–based cropping systems predominate. Rice and wheat require contrasting edaphic conditions. Rice is normally transplanted under puddled soil conditions; the process of puddling leads to destruction of soil structure. Rice and wheat monocropping and the overexploitation of natural resources during the “Green Revolution” led to huge, complex interrelated agronomic and environmental problems, including soil, water, and biodiversity degradation; soil fertility, biota and carbon decline, and nutrition issues; salt buildup and waterlogging; water table lowering; weed infestations and herbicide resistance; and diseases and pest problems. All these issues have been extensively reported and are seen as the major causes of stagnating crop yields and declining profitability of rice-wheat farmers. Implementing the concept of CA in the R-W system is a major challenge for researchers and farmers.

In the late 1990s, the resource-conserving technologies (RTCs) concept emerged as a response to the unsustainability of the R-W system. RTCs are a package of alternatives, including zero- and reduced tillage, surface seeding, bed planting, real-time N management using the leaf color chart, residue management, paired-row planting, single deep placement of fertilizer, laser leveling, controlled traffic, etc., which are "*scale-neutral*" and accept "*divisibility*" in application and proved usefulness in diverse situations in the IGP.

The emergence of an effective and dynamic innovation system assembling efforts of the public and private sector, national and international research institutions, extension services, and innovative farmers led researchers to develop and fine-tune adapted systems and implements and to improve knowledge on RCTs. As a result, ZT for sowing wheat, after puddled rice, bed planting of wheat, and laser leveling found rapid acceptance. The increase in ZT-wheat surface in the IGP is noticeable: 400,000 ha in 1998 and more than 2 million hectares in 2004. The reasons seen are that RTCs help to get timely planting, improve the yield of winter crops, save irrigation water, and reduce the cost of cultivation and population of herbicide-resistant weeds. ZT markedly reduces fuel consumption and wear and tear on tractor parts and accessories. It has been observed that medium and large farmers who have greater capacity to absorb the risk of practicing RCTs are often the first to experiment with RTCs. But soon, the landless, farm holders with leases, and small farmers become enthused from learning from their neighbors.

The use of a soil cover is still difficult. Demand for crop residue for cooking fuel and animal feed is high in the region and many farmers are used to burning rice residue in the field to be able to sow a timely wheat crop. Substantial and continued efforts are being made by stakeholders to improve the systems through additional options such as mulching, green manuring, brown manuring and double no-till, and crop diversification. A new generation of drills able to seed in loose residue is being developed to encourage farmers to avoid burning rice straw and promote its use as mulch.

The socioeconomic impact of RTCs is still not clear. Mechanization of field operations and the use of herbicides reduce employment in agriculture and affect women, who are more involved in rice systems.

In Vietnam, unsustainability of rice- and maize-based systems on sloping lands due to excessive soil erosion seems to have been the major driving force for direct seeding of mulch-based agriculture. This proved to be very effective in reducing soil erosion and weed infestation, and in improving yields. However, long-term agronomic, socioeconomic, and environmental impacts are not yet known.

Drivers and constraints for further extension of CA in KASSA platforms

In the European and Mediterranean platforms, CA does not change yields markedly. On average, yields on poor and medium fertile soils do not change (+/– 10%); they decrease slightly on very fertile soils with a high intensive level of production. In Eastern Europe, yields are expected to increase by 5–10%, mainly on the Ukrainian chernozem. In the Mediterranean countries, most of the studies carried out in Spain and Morocco concluded that yields are generally 10–15% higher under no-tillage, especially in dry years. Change in yields in these regions does not appear critical to the decision of farmers whether to adopt CA or not.

In both European and Mediterranean platforms, scientific evidence of the long-term economic impacts of CA is rare. However, it seems clear that, except for Norway and Germany, where reduced tillage is subsidized, the reduction in production costs acts as a powerful driving force for CA adoption. Soil and water protection and erosion reduction provided by CA are recognized by Spanish farmers but these items are not decisive in farmers' decisions.

The short-term socioeconomic benefits that CA provides through the reduction in production costs, the need to improve farms' competitiveness, the current trend of increase in farm size, market globalization, and the steady increase in fuel cost are probably sufficient to boost CA systems within Europe and to overcome farmers' and society's possible reluctance due to socio-cultural barriers or environmental considerations. In many European regions, the shift from conventional agriculture to CA is probably already ongoing.

In the Latin American platform, the crop yield increase at the farm level was extensively reported; however, the decrease in "among-years yield variability" requires long-term, comparative well-designed experiments that are not commonly found. Even so, the report of empirical observations derived from "paired crops" managed under conventional-tilled and NT conditions clearly shows the advantage of NT in average crop yield and the decrease in interannual variability. The response of different annual grain crops varies with different soil tillage systems. Long-term trials showed that NT systems produce higher yields than conventional systems; crop rotation increases and stabilizes yield more than continuous cropping. Field trials in subtropical Brazil comparing conventional-till, RT, and NT systems carried out over 18 years showed that annual variation in yield was not necessarily associated with the type of soil management; it could be accounted for by climatic oscillations and, especially, variations in rainfall during the annual growth cycle. Also, other experiences indicate that in years of rain shortage higher productivity is obtained under the NT system, whereas, during years of normal rain distribution, productivity did not differ among agricultural management systems.

In small-scale farming, CA reduces drudgery, especially for farmers depending on animal draft power. The reduction in total labor ranges from 11% to 46% depending on the crops grown. The reduction in labor peaks throughout the agricultural year is also an important aspect. A labor reduction allows farmers to increase their cultivated area or to undertake other activities that generate additional income, or even to provide help for their neighbors, which is also socially relevant. Total hours for the use of equipment and machinery and the cost of their maintenance, consumption of fuel, and other lubricants as well as employment decrease significantly. A tractor lasts three to four years longer in NT systems than in conventional systems. In large-scale farming, economies of scale are improved. Savings allow increasing crop area and a more efficient use of machinery and labor force. Thus, the greater profitability and smaller risk of the NT system plus crop rotation are due to the increase in gross revenue, and in savings in labor, fuel, lubricant, and maintenance, and depreciation costs of the agricultural machinery.

In the Asian platform, beyond the savings in irrigation, ZT technology provides a total net gain per hectare ranging from $70 to $80 in the northwest to $70 to $140 in the eastern IGP. The higher gains are mainly due to yield improvement. Surveys showed that ZT wheat increases yield by 200 to 400 kg ha^{-1} in India and by 500 kg ha^{-1} in Pakistan. ZT and bed planting reduce irrigation water by 15–20% and 25–50%, respectively; ZT saves about 50 liters of diesel per hectare.

South Asian farmers are attracted toward CA/RCTs as these benefit them in the short term through savings in fuel, labor, and water, and improve the productivity of externally added inputs. They also fulfill the longer-term goals of enhancing the quality of the resource base. Hence, in South Asia, CA/RCTs should be seen as an important component of the national strategy for food security, poverty alleviation, health for all, rural development, enhancing productivity, improving environmental quality, and preserving natural resources.

Discussion

The concept of CA gave rise to a wide variety of farming practices in the context of the diverse KASSA platforms. In Europe and the Mediterranean, practices range from a noninverting plough to reducing the depth of tillage and/or number of passes (RT), to direct seeding within more or less covered soil (NT); these different tillage practices may follow one another in time and may coexist within the same farm land. In Latin America, in large-scale farming, the three CA components seem to coexist, while in small-scale farming they seem to not always coexist, and, in some situations, a plough is intermittently used. In the IGP, ZT wheat is practiced after puddled rice. Hence, farmers adapt their practices to the practical constraints they face and to market opportunities.

Results show clearly that RT and especially NT greatly cut production costs in all the agroecosystems considered in KASSA. This reduction seems to be the major common feature when soil tillage is reduced or eliminated. However, the magnitude of the reduction depends on many factors, including soil, crop rotation, machinery, cropping and farming systems, etc. Data related to input costs (fertilizer, irrigation, and pesticide) and to socioeconomic aspects of CA remain unfortunately scarce and do not allow drawing a comprehensive picture and a realistic comparison among countries, cropping systems, and farming conditions. Labor savings in particular may allow (1) increasing agricultural area, (2) developing other agricultural or nonagricultural activities that generate additional income, and (3) developing activities of cultural, social, or educational value. But, the long-term effect of a labor reduction on employment and rural development is still not clear. Also, the savings may be offset by additional costs induced by plant control, and it is reasonable to argue that the rise in the cost of pesticides and/or heavy infestations of weeds, pests, and diseases may lead farmers to favor specific marketable crops or to go back to conventional practices.

Scientific evidence of the long-term economic impacts of CA is rare in the KASSA platforms. It seems clear that, except for situations where CA is subsidized, the reduction in production costs has been the major driving force for CA adoption. Change in yield induced by CA and the resource/environment considerations seem to not play a decisive role in farmers' decisions whether to adopt CA or not. Soil and water protection and erosion mitigation provided by CA may be recognized by farmers but these items are not crucial in farmers' decisions. In Brazil and Argentina, soil erosion problems were the historical cause that led to CA development, but small-scale farmers are still not adopting CA.

Hence, cost savings in machinery, fuel, and labor remain the most important economic element that makes CA attractive and drives its adoption. Increased global and regional competition will certainly urge farmers to seek reduced production costs and improved agricultural productivity. CA may be a means to achieve these goals. However, according to KASSA findings, development, dissemination, and sustainability of CA-based systems are affected by many factors acting as drivers or constraints on-farm and off-farm (Table 1). Most of these factors are reversible: drivers can become constraints and vice versa. The factors listed in Table 1 make it clear that CA is not equally appropriate for all agroecosystems. This is in accordance with observations and conclusions made by other authors (Håkansson 1994, Rasmussen 1999, Munkholm et al 2003, Pratap Narain and Praveen Kumar 2005, Ramakrishna et al 2005, Wani et al 2005). The use of a cover crop and diversified crop rotations is still hardly practiced because of climate and soil limitations, length of the growing period, a lack of adapted crop varieties, difficult management of crop residues in wet and dry conditions, competition for crop residues, and general market conditions. Thus, the mechanical control of weeds provided by a plough in conventional systems is replaced by chemical control in CA systems, which is made easier by the availability of affordable and effective chemicals. As a result, in some situations, the number of herbicide treatments increases on average. The lack of knowledge and technical references on biological control of weeds using the competitive and allelopathic properties of intercrops and associated crops in CA systems makes the integrated management approach more risky for farmers. This may explain why farmers in Europe, the Mediterranean, and Brazil return partly or definitely to the plough after years of practicing CA, even if they perceive the effectiveness of CA practices in increasing soil organic matter and earthworm activity, reducing soil erosion, and improving water infiltration and productivity in dry conditions.

The conversion from plough-based agriculture to CA-based agriculture is not a straightforward technical change. The development of CA systems and their socioeconomic and ecological sustainability are highly site-specific. The fine-tuning of CA systems requires a continuous adjustment that calls for permanent knowledge generation and sharing among stakeholders. Success in the shifting process requires (1) a substantial research effort on CA systems to generate knowledge needed to develop, adapt, and improve site-specific attractive CA technologies and options, and to assess/anticipate their long-term impacts; (2) creating favorable conditions allowing a significant involvement of leader farmers and farmers' organizations, private companies, and extension services in the shifting process and the improvement of their knowledge and management skills; and (3) a favorable institutional and policy environment allowing all stakeholders to interact within an effective innovation system able to generate, improve, and disseminate knowledge.

Conclusions

A reduction in production costs is the major common feature of CA in the KASSA platforms. It acts as a powerful driving force for CA adoption. In addition, CA technology significantly reduces the consumption of scarce resources: a reduction in fuel is general; evidence of long-lasting machinery with less maintenance cost has been provided by the Latin American platform; evidence of a reduction in water consumption has been provided by the R-W system in the IGP; no evidence has been provided regarding fertilizers and pesticides. The effects of CA on major gains in crop yields are expected to result from changes in soil physical, chemical, and biological properties, which will likely come about only with time. However, a recent study (Deen et al 2006) showed that a change in yields occurs in the early years of NT adoption; the length of time under NT had a minimal impact on crop yield response to the NT system.

Soil, water, biodiversity, and environmental concerns do not appear decisive in the decision of farmers whether to adopt CA or not. We can assume that these concerns (1) are likely to contribute more in the adoption of CA when farmers get involved in innovation and learning processes, and (2) are unlikely to discourage farmers that adopt CA to go back to the plough when their production costs increase.

Market globalization, the need for farmers to improve their competitiveness, and the steady increase in fuel cost are likely to boost CA systems in many parts of the world. In Europe and the Mediterranean, the conversion process is likely already ongoing; the process is mainly farmer driven and the major driving force is the short-term benefits provided by CA systems through a reduction in production costs.

The lack of scientific documentation of the long-term agronomic, socioeconomic, and environmental impacts of CA systems as well as lessons learned from past and ongoing experiences with CA lead us emphasize the need to anticipate the conversion process in order to improve the long-term sustainability of CA. This calls for a substantial systemic and multidisciplinary research effort, which certainly requires, more than the involvement of local institutions, leading farmers, farmers' societies, and research staff, the involvement of the international research community.

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