

DIRECT SEEDING MULCH-BASED CROPPING SYSTEMS (DMC)

An alternative to
conventional cropping systems
in developing countries



Contents

e. F. Tivet

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Preamble

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PREAMBLE

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Farmers in developing and developed countries have had to deal with acute soil degradation problems caused by soil and wind erosion, with an impact that reaches far beyond the initial areas. This degradation and concomitant loss of natural resources have very serious socioeconomic consequences—poverty, famine and outmigration. Everyone remembers the dust bowl, which darkened the skies over the grain fields of the American Great Plains in the 1930s. Excessive tillage and monocropping were the main causes of this phenomenon.

It is now essential to find alternatives to conventional cropping systems so as to preserve and restore agricultural soil fertility. In USA, in the 1960s, new alternative agricultural practices were tested, i.e. direct seeding mulch-based cropping systems (DMC), based on two concepts: no tillage and direct seeding in mulch of residue from the previous crop. This movement started in USA, developed and gained momentum in Brazil, and then spread to Latin America, Australia, Asia and Europe (including France), and finally Africa. Now more than 95 million ha are cultivated by direct seeding. In the 1980s, in the Brazilian *cerrados* and small family farming areas, CIRAD (French Agricultural Research Centre for International Development/*Centre de coop ration internationale en recherche agronomique pour le d veloppement*) and its Brazilian partners managed to adapt direct seeding mulch-based cropping systems for application in tropical farming conditions. For almost 10 years, AFD (French Development Agency/*Agence Fran aise de D veloppement*), FFEM (French Global Environment Facility/*Fonds Fran ais pour l'Environnement Mondial*) and MAEE (French Ministry of Foreign and European Affairs/*Minist re des Affaires  trang res et europ ennes*) have been backing the process of adaptation and dissemination of this 'sustainable agriculture' within the framework of rural development projects carried out under a broad range of agroecological and socioeconomic conditions in developing countries.

This portfolio, which is the result of a collaboration between AFD, CIRAD, MAEE and FFEM, is devoted to this new farming concept and aims to boost awareness, beyond the tight circle of involved scientists, on what can be considered a genuine agricultural revolution. We hope that it is a useful contribution to the initiatives of all partners of projects supported by French national aid agencies in this field to promote sustainable and yet cost-effective agriculture. Global degradation of soils is not an unavoidable fate, we can give current and future generations effective tools to preserve them.



Note to readers

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NOTE...

PORTFOLIO DESIGN

The aim of this portfolio, which is the result of a collaboration between AFD, CIRAD, MAEE and FFEM, is to boost awareness beyond the small circle of scientists and project leaders involved in various programmes to promote the dissemination and adaptation of DMC practices worldwide—not only the key principles but also the different associated agricultural, ecological and socioeconomic topics. This portfolio was designed and produced by Agropolis Productions (Montpellier, France). The summary presentations, in the form of easy-to-read, illustrated colour information sheets, aim to enhance public awareness on successful results obtained in different countries where the transversal programme for monitoring and support (PTA) has helped to promote agroecology and develop expertise in this field.

OBJECTIVES

- Boost public awareness on DMC
- Promote and disseminate agroecology research and development results
- Give readers a general overview and references for further reading
- Present case studies to give readers solid examples of successful DMC projects in developing countries
- Enhance the awareness of local stakeholders and decision-makers on DMC
- Boost prospects for DMC dissemination

TARGETED READERS

This portfolio targets a broad (but informed) readership, including French- and English-speaking decision-makers, students, scientists, local stakeholders (e.g. technicians, NGOs, public service staff), etc. It will be disseminated throughout the world and should be considered as a general overview to be tailored to the specific setting and concerns of each country or region. It thus presents the DMC theory, actual case studies, multidisciplinary topics and discussion notes on the dissemination and appropriation of these techniques by end users, i.e. farmers in developing countries.

A TWO-PART PORTFOLIO

The left folder includes information sheets dealing with the DMC theory (principles, impacts multidisciplinary topics). The right folder includes information sheets concerning real aspects of DMC (DMC dissemination, adoption and case studies).

FOUR GENERAL FOCUSES

- 1 DMC: definition, principles, function and benefits
- 2 DMC and global environmental issues
- 3 DMC action research initiatives in different countries
- 4 DMC training, dissemination and adoption

Each section consists of several information sheets of the same colour, with each covering a different aspect. The first information sheet of each focus presents an overview, the contents and the 'For further information' section, which includes the main bibliographical references and websites queried on the topic. These information sheets were not designed to provide exhaustive coverage of each focus, but rather to kindle readers' interest and provide them with an overview of the topics. Contact addresses of specialists are provided on each information sheet to enable readers to explore the topics in greater depth if they wish. Each sheet can thus be read separately. However, relevant cross-reference tags are given in the text so that readers interested in a particular topic can refer to another information sheet to obtain further details. Each cross-reference tag includes the colour of the focus and the number of the relevant information sheet.

GLOSSARY

Words and expressions underlined in the portfolio texts are explained in a separate information sheet at the end of the portfolio.

ABBREVIATIONS AND ACRONYMS

These are defined in a separate information sheet at the end of the portfolio.



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Agroecology action plan overview



The global agroecology action plan (AAP) combines initiatives of the main French aid agencies, including the French Ministry of Foreign and European Affairs (MAEE - DGCID), the French Development Agency (AFD), the Agricultural Research Centre for International Development (CIRAD) and the French Global Environment Facility (FFEM).

The main aim is to develop systems based on agroecological methods that are adapted to different constraints and farmers' needs, and to test their advantages and drawbacks with a view to their potential dissemination/adoption on a countrywide scale. These will be developed at selected sites in five pilot countries in the Priority Solidarity Zone (PSZ): Tunisia, Mali, Laos, Madagascar and Cameroon. The AAP has two main components:

- **A set of projects to adapt agroecological techniques in representative PSZ countries** with a range of agroclimatic zones and socioeconomic settings. These projects are generally integrated in the form of agroecology research and development components within larger AFD rural development programmes. FFEM and CIRAD provide joint funding for technical assistance.
- **A transversal support programme (PTA)** to ensure the consistency of the different initiatives, provide complementary technical support, facilitate communication and exchange of different results, capitalisation and knowledge transfer. This programme was launched in 2000.

The AAP is managed by a steering committee that includes MAEE, AFD, FFEM and CIRAD. It is chaired by MAEE/DGCID, with AFD heading the Secretariat.

TRANSVERSAL PROGRAMME FOR MONITORING AND SUPPORT (PTA)

The PTA has five components:

• COMPONENT 1: Project identification support

- *Facilitation of the identification and funding of rural development projects* including an agroecology component, especially by supplementing project feasibility studies with a specific agroecology expert appraisal and conducting complementary socioeconomic studies.
- *Financing decision-makers' awareness trips.*

• COMPONENT 2: Project follow-up

The aim of this component is to provide technical and scientific support for pilot projects under way so as to ensure quick dissemination of these innovations:

- *Expert appraisals during implementation of the agroecology component*, in the form of occasional support missions to promote development of these innovative techniques. The technical skills gained in some pilot projects can thus be quickly disseminated in other countries.
- *Methodological work to adapt these new techniques.* Substantial technical references are available from large-scale mechanized farms in a humid and semi-humid tropical area of Brazil. Fewer technical references are available from smallholdings in drier regions.
- *Setting up monitoring-assessment of initiatives conducted.* Regular monitoring-assessment missions in different concerned countries have enabled a comparison of different projects, while identifying factors that hamper dissemination of these techniques.

• COMPONENT 3: Promotion, training and dissemination of results

Training and dissemination of results were the focus of considerable efforts, through:

- *Training and experience exchanges* via workshops, research trips, and training, addressing a very broad audience in developing countries.
- *Communication and promotion of results:* creation of a website, setting up networks, regular dissemination of a newsletter, publication of technical extension documents.

• COMPONENT 4: Carbon sequestration assessment

Within the framework of the Kyoto Protocol and carbon markets, the agroecological carbon sequestration capacity could become the focus of agricultural subsidies in developing countries.

• COMPONENT 5: PTA monitoring and control

Financial audits, end of project external assessments and support for the steering committee secretariat to ensure monitoring and coordination of the transversal programme for monitoring and support.

DIFFERENT PTA STAKEHOLDERS

Different French institutions are involved in the PTA:

- **AFD, French Development Agency**
(*Agence Française de Développement*)

Key operator of the French official development assistance policy, under the joint supervision of MAEE and the French Ministry for the Economy, Finance and Industry, AFD's mission is to participate in funding economic and social development projects/programmes in many foreign countries. AFD is involved on five continents, striving to reduce poverty, fund economic growth and protect global public goods. Its activities come within the framework of the Millennium Development Goals.

For further information, see the AFD website at:
www.afd.fr/jahia/Jahia/lang/en/home

- **MAEE, French Ministry of Foreign and European Affairs**
(*Ministère des Affaires étrangères et européennes*) - DGCID,
Directorate for Development Policies (*Direction Générale de la Coopération Internationale et du Développement*)

MAEE represents France before foreign governments and institutions and its mission is to develop France's foreign policies. It conducts and coordinates international relations and is the policy advocate. DGCID, alongside the Treasury Directorate, develops public development aid strategies—country strategies and sectorial orientations—and heads discussions on public development aid. MAEE–DGCID supports the AAP that provides partial responses to issues such as food security, combating desertification and environmental conservation, which are part of its action strategies.

For further information, see the MAEE website at: www.diplomatie.gouv.fr/en/

- **FFEM, French Global Environment Facility**
(*Fonds Français pour l'Environnement Mondial*)

FFEM is a bilateral fund which was set up in 1994 by the French government following the Rio Summit. Its aim is to promote protection of the global environment in developing and transitional countries. FFEM contributes to the funding of AAP with respect to controlling the greenhouse effect. Indeed, the cropping techniques implemented have a positive impact on carbon sequestration in soils, thus reducing atmospheric carbon levels. These cropping techniques also have a positive impact in combating desertification and on surface water systems.

For further information, see the FFEM website at:
www.ffem.fr/jahia/Jahia/site/ffem/lang/en/accueil

- **CIRAD, Agricultural Research Centre for International Development**
(*Centre de coopération internationale en recherche agronomique pour le développement*)

CIRAD is a French agricultural research centre working for international development. Most of its research is conducted in partnership. CIRAD has chosen sustainable development as the cornerstone of its operations worldwide. It contributes to development through research and trials, training, dissemination of information, innovation and appraisals. Its expertise spans the life sciences, human sciences and engineering sciences and their application to agriculture and food, natural resource management and society.

For further information, see the CIRAD website at: www.cirad.fr/en/index.php



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And with the participation of:

- **Jean-Claude Quillet, French farmer**

Jean-Claude Quillet owns a farm in Touraine region, western France, where he grows forage cereal crops. Over 10 years ago, he discovered agroecology techniques through exchanges with farmers in Brazil and Argentina and now cultivates all of his fields under DMC. He currently contributes to South-North exchanges to promote this type of agriculture, offering his technical expertise to help farmers within the framework of different projects.

- **Claude Bourguignon, Director of the *Laboratoire d'Analyse Microbiologique des Sols* (LAMS, France)**

LAMS is a laboratory that conducts soil analyses and expert appraisals for farmers and professional stakeholders in France and abroad. It also assists farmers in developing simplified cropping techniques or DMCs according to the state of their soils and the soil-climate zone. LAMS also offers advice and analyses to enhance soil management. It is an officially recognised training centre for agricultural professionals and offers personalised training courses in specific domains such as viticulture and cereal cropping. ■

For further information, see the LAMS website at: www.lams-21.com

DMC at a glance

A quick DMC refresher for hurried readers...

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AT A GLANCE

In response to current global environmental issues—desertification, biodiversity loss, global warming—humankind must absolutely modify its ‘environment-unfriendly’ practices, especially in agriculture. The negative impacts of conventional agricultural practices are well known (land degradation, soil erosion, decline in biodiversity, pollution, desertification, etc.), in addition to all of their dramatic social implications (famine, poverty, out-migration, etc.). It’s time to change! Global food needs are rising with population growth. Agricultural production has to be increased to fulfil these pressing needs. Agricultural systems capable of meeting this challenge must now be productive, profitable and sustainable—increasing production and the quality of produce, boosting farmers’ income, while preserving natural resources and the environment. Through their many positive impacts in the field and globally, DMCs can effectively meet this substantial challenge in both developing and developed countries.

■ What are DMCs?

DMC is a new tillage-free agricultural approach that has short- to medium-term effects with respect to halting erosion, increasing soil fertility, stabilising or even increasing yields, even on infertile wastelands, while also reducing fuel consumption. This innovation is based on three concepts that apply in the field, i.e. no tillage, permanent plant cover, and relevant crop sequences or rotations associated with cover plants.

■ How do they work?

These techniques involve sowing crops directly in permanent plant cover (residue from the previous crop that has been left on the ground, in addition to mulched dead or live cover). This cover protects the soil from rainfall stress and nourishes microorganisms that vitalize the soil and enhance its fertility. The use of strong-rooting efficient plants (restructuring fibrous root systems of grasses, powerful taproots of atmospheric nitrogen fixing legumes) in cropping sequences promotes impressive ‘biological tillage’ of the soil in conjunction with the work of earthworms, which are in turn preserved because of the absence of tillage.



© L. Séguy

■ Where are they used?

In 2005, 95 million ha were cropped under direct seeding systems worldwide. DMCs are mainly implemented on a very large scale in Brazil (almost 24 million ha in 2005). Through the initiatives of CIRAD (L. Séguy), they have also been adapted (or adaptation is under way) to small-scale family farming conditions in developing countries (Madagascar, Mali, Laos, Cambodia, etc.). DMCs can be adapted and used under most socioeconomic and agroclimatic conditions in the world, and it is even possible to recover land that has been left idle (considered as wasteland) under conventional farming conditions with tillage.

■ What are the benefits of DMC?

DMCs offer major agricultural, environmental and socioeconomic advantages:

- **From an agroenvironmental standpoint**, DMCs halt soil erosion which is responsible for waterlogging and destruction of crops and downstream infrastructures (very costly hydroagricultural structures, roads, ditches). By restoring the plant cover, they control runoff, stimulate biological activity in soils, reduce water needs and sequester carbon in the soils (1-2 t/ha/year of carbon, depending on the ecosystem), thus helping to control climate change. DMCs also reduce disease and pest pressure on most crops under all soil-climate conditions.
- **From a socioeconomic standpoint**, DMCs markedly reduce weeding and tillage operations, as well as associated labour and equipment costs. Yields are stabilised or even increased under a broad range of climatic conditions and cropping systems. Moreover, DMCs do not require large equipment such as tractors or treatments with massive quantities of fertilizers, which are beyond the means of the poorest farmers. Indeed, DMCs can be implemented by smallholders with just 0.25 ha of land or owners of large-scale plantations!

■ Why do these techniques interest even the poorest farmers?

DMC techniques are very popular amongst farmers due to the possibility of increasing their income, reducing laborious work and labour time, enhancing biodiversity (production diversification), thus boosting their food and economic security. The personal benefits, and primarily the increased yields and financial savings, are highly attractive features for farmers. They may also be attracted by the overall benefits for society and the environment, but these aspects are chiefly of interest for governments and the international community (Kyoto Protocol, land management, etc.).

DMCs are compatible with all types of mechanization, from simple hand tools to precise agricultural machines, so farmers of all socioeconomic categories are thus concerned. Special equipment has been developed for a range of farming systems. Many plants have already been identified as efficient cover species, and may be adapted to different soil-climate conditions worldwide.

■ Towards a new paradigm?

When farmers adopt DMC, major changes are necessary in their crop management patterns (fields) and in the organization and management of farms and the agrarian region. DMCs are relatively complex from a technical and intellectual standpoint—these new agricultural paradigms require relatively long development and adaptation periods, a substantial stakeholder network and major changes in peoples' strategies and priorities, which may take a few years or as long as one or two generations. DMC is not simply a technical package that can be disseminated, it is a set of practices, methods, systems, etc., and the changes cannot be made from one day to the next! The change process may also be hampered by cultural and social barriers due to tight attachments to conventional farming practices (with tillage, 'clean' fields, etc.). This represents a major change in mindset for farmers, as well as for other associative, political and institutional stakeholders.



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■ How are DMCs disseminated?

Since DMC is not a technical package but rather an important change affecting the farm and even the entire community, farmers must be efficiently trained to ensure successful dissemination of this innovation. The challenge is thus now to provide farmers and agricultural technicians with ready access to training on DMC techniques. This means organizing the social changes required for large-scale DMC dissemination.

Farmers require constant supervision from the outset to facilitate their adoption of these techniques. The public sector and non-governmental organizations (NGOs) should promote this access to information, specific training and farming practices. Between-farmer exchanges via associations and networks are highly efficient and beneficial in this respect. Farmers' organizations indeed play a very important role with respect to adoption, training, information exchange and innovation. Networks are also important to facilitate exchanges between different countries or regions where farmers may be experiencing the same problems but the solutions may differ.

■ What factors hamper DMC adoption by farmers?

Farmers may lack financial resources during the transition phase and for buying special equipment. They may also have to cope with a temporary drop in income. In this setting, regulations and governmental programmes should offer financial incentives to support farmers' initiatives, while also actively backing farmers' organizations and networks. The fear of having to deal with problems arising during the initial transition to DMC is actually the main factor hampering dissemination of this innovation.

DMC adoption can also be delayed by an adverse political environment (e.g. import subsidies) and also by social factors such as traditional common grazing rights (e.g. in Africa), and age-old habits concerning tillage, etc. Access to equipment and inputs is also a key constraint to DMC adoption. The private sector thus has a major role to play, especially by providing ready access to equipment required to implement DMC. ■



Conventional system (cotton)



DMC (cotton)

© M. Thézé

These two plots are 5 m apart (northern Cameroon).

An interview with the pioneer of French DMC research

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INTERVIEW

Lucien Séguy, a CIRAD agronomist, has been assisting farmers in developing countries on the development, installation and dissemination of DMCs, especially in Brazil, where he has been working since 1978.

■ What would you say to people who claim that direct seeding is not biological (or organic) agriculture?

L.S. They're right. It is not organic agriculture—it is even more biological! In DMC, biology is the motor that drives soil-crop interactions. Organic agriculture involves tillage. With climate change, over the last few summers, we've been getting tropical-type storms with extremely high rainfall intensities. With rains like that, tilled soils are carried away in a river of water. What is this organic agriculture in which soils can disappear after two or three rains? Also, organic agriculture has still not been able to get rid of, let's say, the chemical coating. By tracing chemical products, it has been found that pesticides are still present despite all of the guarantees and the highly complex specifications that must be met.

Even organic agriculture cannot guarantee that food will be clean. Maybe there's not enough traceability monitoring to ensure that the food products will be absolutely clean. But what shocks me most is that soils that have taken millennia to form are left to be carried away by the first rain. What can be done next? What's happened to the biological agriculture? It should be built on completely protected soils without **externalities**. And certainly all of the most toxic chemical molecules for humans and the environment should be eliminated. DMC, as compared to organic agriculture, has been focused on (in the initial phase and up until now) completely controlling erosion and externalities, even under the harshest climates (with rainfall of 2.5 m). Protecting soils under all ecological conditions is already an incredible challenge!

■ How is clean production possible with DMC?

L.S. For 3-4 years, the second phase of our team work is an operation called 'clean seed'. There wouldn't be any problems with crop protection products if they quickly degraded and if their residues, their molecules, were not toxic to the environment or humans. However, it's known that this is not the case, they are carried into other environments like rivers and water tables. The process is completely reversed in DMCs. There is an interesting explanatory mechanism that would deserve to be widely considered by scientists interested in fundamental mechanisms. In DMC, the soils are always protected by a layer of up to 15 cm deep (permanent cover) and are never exposed. In the Amazon, if I place temperature probes in forest soils and in adjacent DMC plots, on the same soil, I get the same temperature reading. It's a buffer effect of the cover.



It's also a nutrient medium for all fauna that is going to process and break down this matter, and facilitate organic matter mineralization. When pesticides are used in DMC, the molecules are intercepted by the crops and plant cover, not the soil or the soilborne fauna—the soil is completely protected by the cover!

Secondly, under suitable conditions, this protective layer is literally digested within 2-3 months. Any chemicals that have missed the crops will, under DMC, impregnate the litter covering the soil. Since this litter is digested by all of the soil activity—fauna and microflora, real processing reactors—toxic molecules are also digested, and thus sometimes lose their toxicity. This is where there are fundamental topics for research. What remains of these toxic molecules? Personally, I hypothesize that there's nothing left. It's a self-cleansing system. It's biologically cleaned without intervention. All trends that have been measured on this mechanism tend to converge—a beginning of a proof. But I would go even further. As I'm still not entirely convinced and since it should be tested under all climates and with all types of cover, I would gradually remove the chemistry of DMC systems and replace it with organic molecules, since they can be widely used to treat large areas* and their costs are not any higher than those of 'all chemical' systems, with equivalent performances. I've started doing this in France and other countries. The molecules that remain in the seeds and soil are then analysed by the most advanced laboratory tools. I'm currently analysing 138 molecules. I want to be sure that the digester gets rid of all molecules that are toxic to humans and the environment.

The first battle concerns water, not carbon. If nitrates and pesticides are drastically reduced, well, after 4-5 years, the water tables would likely be clean. With DMCs, everything is intercepted and digested in the cover. Nitrates, excluding crop needs, are immediately reorganized in organic nitrogen. In several French regions, with winters when it rains a lot, there are no nitrates below 30 cm (measured by different chambers of agriculture). This is maybe the most revolutionary aspect of DMCs!

* With the range of organic molecules currently adjusted under DMC, liquid humus is used as a substitute for part of the fertilizers, elicitors to replace fungicides and stimulate the immune defence mechanisms of crops, NEEM and Bt derivatives to control pest insects, and amino acid complexes to treat seeds. All of these products are derived from renewable biomass.

■ Do GMOs have a role to play in DMC systems?

L.S. As early as 1994, I did not believe in the sustainable efficacy of RR GMO (Roundup-Ready, i.e. glyphosate resistant). At that time, I had already written that I knew three plants for which glyphosate treatment dosages should be tripled in Brazil. But glyphosate is not efficient against these dicots. It was thus obvious that forms of resistance would quickly develop since I had already found several within a very short time span. Such GMOs are of no interest in DMC. They could only be useful for 2-3 years, i.e. the time required for the plants to 'turn around', because nature quickly turns around in this respect. Nature is richer and more intelligent and has incredible defence resources. Controlling weeds by injecting Roundup resistance genes could not last long. I pointed that out, and it happened. It even led to all kinds of abusive situations. They say that RRs enable us to save on herbicides, but in fact the doses have to be increased as the flora gets stronger! And there have been enormous accidents!

So the answer is clear, RR GMOs are not essential, or maybe just for 2-3 years. It's an intelligent but very short-term transition technology. Moreover, it's now known that glyphosate has terrible side effects on soilborne organisms. It destroys bacteria that reduce manganese. So magnesium deficiencies are appearing everywhere. On one hand, we think that costs will be reduced with RR GMOs, while on the other, experience shows that on many cereals, and soybean, the side effects (serious imbalances in soilborne organisms, e.g. blight development, manganese deficiencies, increase rather than decrease herbicide requirements, etc.) are much worse than the fleeting advantages of RR GMOs. Research is not a domain in which humility prevails, and if we reflected for a moment rather than giving in to our capacity to modify incredibly complex environments, we could progress much faster, even though it's true, GMOs represent a major commercial revolution.

However, Bt GMOs (*Bacillus thuringiensis*) seem to have a steadier efficacy than RR for controlling various pest insects. Bt GMOs could be very usefully associated with DMCs to reduce production costs for very delicate crops such as cotton that require high-dose pesticide treatments (12-18 pesticide applications on high-technology rain-fed cotton in central Brazil). Finally, GMOs that show promise for producing biological molecules essential for human health would deserve to be associated with DMC to be able to produce them cheaper and cleaner.

■ Could DMCs be implemented under all climatic conditions?

L.S. Definitely! DMCs could even be implemented under climates in which even conventional agriculture systems are not used. Apart from the permafrosts (permanently frozen soils) of Siberia or the Saharan desert! They are possible in all regions worldwide where agriculture is practiced, in all countries, even where little is grown or where high quantities of inputs are required. All schemes are possible! Thanks to DMCs, we can now cultivate environments that could not be managed by conventional techniques because of their sensitivity to water or different extreme climatic conditions. DMCs protect the soil, acting as a buffer against harsh temperatures and other climatic conditions, and regenerating soil fertility under cropping conditions.



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■ Do competitions between main crops and cover plants substantially hamper DMC implementation?

L.S. In well set up DMCs, there should not be any competition between main crops and cover plants. This is the role of tests, of upstream research. We have created systems in such a way that there is no competition between species, either by staggered sowing, or by selecting cover plants that do not have the same water and nutritional needs and that do not live at the same level of the crop profile. DMCs have to be considered as a system, i.e. developing the system as a whole with its functioning modes rather than promoting a single crop. We assessed all possible climatic conditions, and managed to triple production. If it is well managed, then it is clearly understood! We know the laws that regulate the functioning of these systems, and they function everywhere, which means that there is a universal side to these functioning laws. It is the only technique in the world that enables farmers to crop intensively (highest and most diversified production potential) while increasing biological activity and organic matter without any external organic matter inputs.

■ What are the technical limits of DMCs?

L.S. This just depends on the intellectual and practical capacity of people to conceive and create technological innovations and make them progress. Since the outset, DMCs have been continuously progressing with respect to their properties, capacity to sustainably produce and their advantages. The 'clean seed' operation currently interests civil society because consumers want to consume clean food. Maybe this could be backed by traceability monitoring. The next step would thus be to see if collaborations are possible with supermarkets on the basis of the fact that these products are different and free of toxic residues. This would be commercially valid and the differential prices could benefit farmers!

■ Who are DMCs designed for?

L.S. DMCs are designed for agriculture, all forms of agriculture. DMCs are not reserved for large-scale farms. Regardless of the situation, enormous erosion phenomena, under much harsher climates than ours, triggered changes in cropping techniques. DMCs are currently developed for all farm types. We could create thousands of systems based on our experience in Madagascar and Asia. We have now created 50-60 different systems. One of the great successes of primitive conventional agriculture in all countries of the world was to combine several different plant species. This enabled farmers to cope with economic variability of all types. It is thus a buffered environment that responds to an average stable production level. Farmers are very familiar with these concepts. It is thus easier, by small-scale farming traditions that promote biodiversity in limited areas, to set up DMC systems in this setting rather than in large-scale mechanized predominantly monocropping farming conditions. Indeed, one of the major technical pitfalls on such farms has been to conduct mechanized harvests of all plants together, which boosted costs. This is exactly the kind of scenario that we want to avoid in the current setting! Even with machinery, DMCs enable farmers to avoid monocropping (monocrops cannot be managed under DMCs). This has enhanced biodiversity in agrosystems. However, to create all of these systems under different ecological and socioeconomic conditions, a naturalist's approach is essential to be able to assess transformations, under all forms (quantitative, qualitative, sociocultural), in physical and human environments induced by DMCs as they evolve. We are currently disconnected with nature and it is urgent to get naturalists back in nature because our entire future depends on it!

■ What could stall their dissemination in developed countries?

L.S. There are many different arguments, depending on the regions and mentalities. For a developed country like France, I would say that it, like the rest of Europe, is living in a privileged situation that it is striving to keep. As of 1992, I was involved in conferences in which I told farmers that they were going to lose their bonus schemes. They didn't believe me. But that's exactly what's happening! While some farmers tended to abandon, others have long decided to prepare for the post-CAP period. First by reducing their input costs and applying them more rationally, and then by trying to reduce their mechanization costs. DMC is at the crossroads of these concerns and its adaptation by French farmers, like J.C. Quillet* since 1994, has enhanced their farming prospects—improved cost-effectiveness, regular yields, reduced negative impacts on the environment, etc.

Subsidies are generally hampering DMC dissemination in France. The constraints can also be linked with a lack of organization to undertake the change, to the absence of sustainable results, supported by substantial prior experience, etc. And finally, I would say that the main problem at the beginning of this century is the lack of action and involvement! Indeed, involvement is the key to getting results and ensuring technological change. So major risks can be taken. We have to stop talking and act! The situation always ends up badly when we are protected from everything. That's not what life is all about.

* Jean-Claude Quillet owns a farm in Touraine region (western France) where he crops cereals under DMC. NDLR.

■ How do farmers view the change in technical message recommended by developers? How does this change in paradigm occur?

L.S. This is a multifaceted question. In Brazil, for instance, farmers are mostly young (28-45 years old) and open to change. Farmers' associations were immediately created. People have a long future ahead of them towards which they look, over there! That's also an important fact. When people are stuck, they generally change. When the situation begins to sour, changes come very quickly, sometimes within a year. As they have no credits, what can they use as techniques to survive? The cheapest first! This is how DMCs entered the scene, i.e. by their qualities, production cost savings and the fact that they are easy to implement. So farmers change, even when they are not completely convinced at the beginning. However, we in Europe are in a bad position because of our comfortable privileged situation with nothing lacking—and we believe this will last forever.

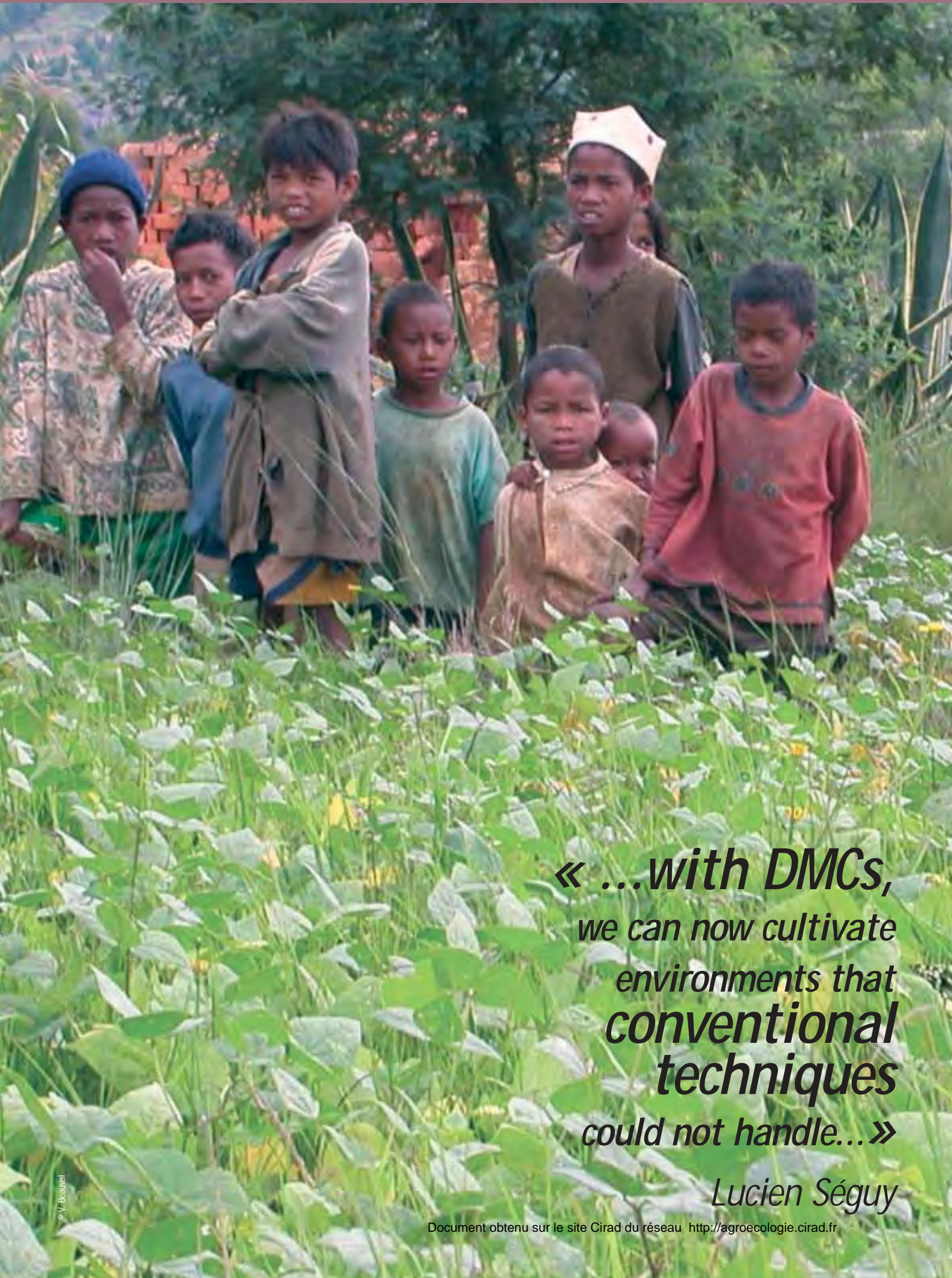
■ What should we do to ensure that DMCs will be politically recognized in France and throughout Europe?

L.S. The French approach should be:

1. First get elected authorities interested and convinced. Current results obtained on DMC pioneer farms in France are solid, established, often spectacular and reproduced under many ecological settings in France. Savings have been made—pollution is halted, roads are no longer damaged by surface runoff, etc. 40% of current bonuses could be quickly dropped!
2. It should also be suggested to top-ranking politicians that current bonuses (or part of them) could be used, before their pending elimination, to assist technological change. One solid measure would be to attribute bonuses for transitions to DMC. That would provide a good incentive and farmers would be less afraid of the change. The fear of having to deal with problems arising during the initial transition to DMC is actually the main factor hampering direct seeding dissemination.
3. Solid platforms have to be set up to enhance farmers' awareness and training, with comparisons between DMCs and conventional cropping systems. People could even be required to pay to visit these platforms. That would finance the supplementary costs required to set up these small regional units.

■ Has there been any progress with respect to taking DMCs into account in policies in the pilot countries?

L.S. In Brazil, it's clear—successive economic restructuring quickly resulted in the promotion of direct seeding based on the associated reduction in production costs, which has enabled Brazilian agriculture to enter the global arena without subsidies. It has gone even further than that. An intelligent network of direct seeding associations managed by a very dynamic national federation took over the whole country. In the 1990s, EMBRAPA (Brazilian research institute) was asked during a major event (involving scientists, multinational corporations, ministers, associations) to focus in priority on direct seeding! On this topic, research was lagging behind development! This got things going right away! Research can sometimes resist change more than farmers! In Madagascar and Laos, for instance, where family smallholdings prevail, DMC is taken into account and a mainstay in national government agricultural policymaking guidelines. ■



*« ...with DMCs,
we can now cultivate
environments that
conventional
techniques
could not handle... »*

Lucien Séguy

DMC: definition, principles, function and benefits

© L. Séguy

Focus 1 of this portfolio presents DMCs from a general and theoretical standpoint, including the basic principles and many benefits associated with their implementation (agronomic, environmental and economic). DMCs are classified within the broad agroecology category. We also felt that this was the best time to define the many terms found in the abundant literature available on this topic.

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1.5 Economic benefits of DMC

The main economic impacts of DMCs at different scales—from the producer to the planet

1.6 Conservation agriculture terminology

Different terms found in the literature

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- Documents that have been published in *La gazette des SCV au Cirad* can be obtained upon request from Michel Raunet (CIRAD), michel.raunet@cirad.fr



Direct seeding mulch-based cropping systems (DMC)

1.1

➤➤➤ An alternative to conventional cropping systems in developing countries

The relevance of tillage-based **conventional agriculture** is currently being questioned since it does not seem to be able to meet the main challenges concerning soil and water conservation, environmental protection, food security, etc. Direct seeding mulch-based cropping systems (DMC) without tillage is a promising agroecological crop management strategy that could more effectively address these issues in developing countries.

KEY AGRICULTURAL PRINCIPLES UNDERLYING DMC

DMCs are new cropping systems that have been developed and disseminated in developing countries by CIRAD and partners since 1985 (L. Séguy and S. Bouzinac). DMCs are classified within the broad agroecological category. They aim to enhance farming cost-effectiveness and sustainability in an environment-friendly manner by simultaneously implementing several principles in the field:

- **Eliminating tillage** and planting crops by direct seeding, whereby seeds are sown directly in untilled soil. Only a small furrow or seed hole of sufficient depth and width is opened using specially designed tools, thus ensuring good soil cover and seed contact with the soil.
- **Permanent plant cover**: the soil is permanently covered with dead or live plant cover.
- **Crop sequences or rotations** in association with cover plants.

The way these principles are combined in the field may vary depending on the local situation: agroecological environment, farmers' resources and objectives, etc. These systems can be adapted to a wide range of environments and thus adopted by different categories of farmers, even the poorest. They have been successfully implemented in various countries worldwide (e.g. Brazil, Laos, Madagascar, Cameroon, Tunisia, etc.).



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WHAT IS AGROECOLOGY?



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Agroecology is a scientific research discipline focused on agricultural, socioeconomic and ecological factors associated with agricultural production,

while also addressing environmental issues (soil conservation, erosion control, biodiversity preservation, etc.). DMCs represent one of the many agroecological strategies.

DMCs CAN BENEFIT FARMERS, COMMUNITIES AND THE ENTIRE PLANET

When the above three principles are properly applied, farmers and the community will reap a number of agricultural, environmental **1.4** and socioeconomic **1.5** benefits. It is a means to reconcile agricultural production, enhanced living conditions and environmental conservation.

Environmental benefits—environment-friendly cropping systems

DMCs emulate the functioning of forest ecosystems, whereby litter left on the soil surface contributes to:

- **Soil protection** and fertility regeneration through erosion control
- **Carbon sequestration**, efficient and high (1-3 t/ha/year)
- **Reduced water consumption** for agricultural production
- **Reduced fertiliser and pesticide dosages**, thus reducing their pollution impact on groundwater supplies and improving food quality and security
- **Enhanced water infiltration** and reduced flooding risk
- **Biodiversity preservation or even enhancement**, contrary to monocropping systems
- **Reduced shifting cultivation**, and thus deforestation in developing countries, thus preserving biodiversity
- **Higher water table levels**

Agricultural benefits—enhanced soil productivity

Plant species used for permanent soil cover produce high quantities of biomass and have powerful root systems, therefore:

- **Creating an environment suitable** for the development of intense biological activity in the soil
- **Increasing organic matter contents in the soil**
- **Providing nutrients** required for crop plants and **recycling** of leached elements to benefit the crops
- **Conserving groundwater** through better infiltration, reduced evaporation since the soil is protected against high temperatures, better **water retention capacity** and tapping of water from deep soil horizons
- **Improving the soil structure** on the surface and in deep horizons
- **Controlling weeds** and plant diseases
- **Increasing crop productivity** (quantity of product generated per volume and time unit)
- **Decreasing the impact of climatic variations** (especially rainfall)

Economic benefits—attractive cropping systems and cost-effective farming activities

- **Reduction in labour time** and laborious work
- **Reduction in labour demand**
- **Reduction in expenditures concerning fuel** (large-scale farms), inputs (fertilisers, pesticides) and equipment acquisition (e.g. tractors), use and maintenance
- **Diversified agricultural production:** associations with livestock production is possible as cover plants can produce excellent forage
- **Production levels that are comparable to or even higher** than levels obtained via modern intensive agriculture, and at minimal expenditure



© L. Séguy

SOCIAL BENEFITS—CONTRIBUTION TO FARMING SYSTEM SUSTAINABILITY

DMCs enhance the sustainability of farming systems, by preserving them and also by contributing to natural resource development and increasing soil biodiversity (diversification of production, microflora and fauna), while not reducing yields or production. The soil—which is often the farmer's only capital—is thus preserved. ■

Principles	Functions/Benefits
No tillage	<ul style="list-style-type: none"> • Soil structure not upset • Erosion control • Rapid crop establishment • Reduced labour • More flexible cropping calendar • Little equipment required • Optimised use of available mineral and water resources: increased yields
Permanent plant cover	<ul style="list-style-type: none"> • Increased organic matter contents, water infiltration and retention capacity of the soil • Fixation of atmospheric carbon and nitrogen (legumes) • Protection of the soil from erosion and enhancement of the soil structure • Increased quantity of nutrients via recycling of leached nutrients from deep horizons to the soil surface where they can be used by the main crops • Reduced evaporative loss of soil moisture • Weed control • Facilitated tapping of deep groundwater • Can be used as forage
Crop rotation	<ul style="list-style-type: none"> • Diversification of agricultural production (food for humans and livestock) • Reduction in risks of disease outbreaks, pest attacks and weed infestation • Better distribution of water and nutrients in the different soil layers • Increased nitrogen fixation through the introduction of legumes • More efficient use of water resources and soil nutrients via sequences or associations with plants with different root systems • Better organic or mineral N/P/K balance • Increased humus synthesis



A FEW KEY FIGURES FROM THE BRAZILIAN EXPERIENCE

Between 1989 (0.8 million ha) and 2005 (20 million ha), the adoption of direct seeding generated savings of:

- 1.8 billion tons of arable soil
- \$18 billion (due to the substantial reduction in production costs and concomitant increased production)
- 2.1 billion tons of fuel
- 800 million tons of sequestered CO₂

(From Borges *et al.*, 2000)

History: no-till cropping to DMC

1.2

© L. Saguy



➤➤➤ What are the reasons underlying the development of DMC?

SOIL DEGRADATION AND EROSION GAVE RISE TO DIRECT SEEDING

The basic concept underlying direct seeding was developed and first implemented in nontropical areas, first in USA as of the 1960s, and then in southern Brazil (subtropical), Australia, Argentina and Canada as of the 1970s. Until then, agricultural practices were based on tillage, repeated spraying of soils and excessive monocropping, which led to very large-scale ecological catastrophies with heavy socioeconomic consequences. The most renowned example is the dust bowl (dust clouds covering infrastructures, fields, etc.) that occurred on the American semiarid Great Plains between the 1920s and 1940s as a result of soil degradation and severe wind erosion. Tillage was partially blamed as early as the 1930s in USA as a result of this national disaster. Comparable phenomena affected Australia in the 1950s and 1960s. In Latin America, direct seeding was first adopted by a few farmers as of the 1970s to curb severe water erosion phenomena in southern Brazil (Parana state) and Argentina, in the Central Pampas. Individual and collective awareness of soil erosion processes triggered the development of direct seeding in these different parts of the world.

DEVELOPMENT PROMOTED BY TECHNOLOGICAL PROGRESS—SEEDERS AND HERBICIDES

The development of direct seeding required the invention, dissemination and management of special agricultural equipment and herbicides. The roles of research and the agroindustrial private sector were crucial to ensure progress in the development of agricultural machinery and herbicides—the construction of new tools and the development of new herbicide compounds. As of the 1940s, North American research was focused on crop protection products and the development of alternative techniques to tillage, e.g. chisel ploughs and other tools for preparing the soil surface for cropping.

As of the 1960s, American farmers abandoned tillage and left crop residue on the ground until the next sowing season. Then they sowed the crops directly in the mulch after knocking down the weeds with herbicides. Existing seeders were then adapted and others developed specifically for direct seeding. With the elimination of tillage, efficient alternatives had to be found for controlling **weeds**. In two key steps, 'chemical tillage' was developed through the use of **nonselective nonpersistent herbicides**, i.e. paraquat in 1960 and glyphosate (*Round-up™*) in 1978 in USA. This latter product was commercially released in 1990, with a drastic drop in price (from US\$40 to 4/l between 1980 and 2000), thus substantially fuelling the expansion of direct seeding. In 2003, over 300 herbicides were already available, so all direct seeding strategies could thus be implemented with tailored chemical weed management.

AN ANCIENT CONCEPT USED IN TRADITIONAL CROPPING SYSTEMS

Direct seeding techniques have been used to grow traditional crops since the beginning of agriculture. Farmers in ancient Egypt and Incas in the South American Andes used a stick to make holes in the ground in which they manually placed seeds and then filled the holes in with their feet. This is still practiced in some farming systems in the tropics, e.g. in humid tropical forest areas where many farmers traditionally practice subsistence **shifting cultivation**, whereby fields are cleared by burning, cropped for a short period and left fallow. Hundreds of thousands of hectares are still sown traditionally by roving farmers using this technique and direct seeding in forest regions of Latin America, Africa and Asia.

MASSIVE DEVELOPMENT OF MECHANIZED AGRICULTURE IN USA AND LATIN AMERICA VIA THE DRIVE OF PIONEER FARMERS AND 'ATYPICAL' SCIENTISTS

Groups of pioneer farmers have become mobilised, along with scientists (public and private), in response to the degradation of their land to invent new farming methods. These pioneers and atypical scientists have had a considerable impact in boosting the awareness of other farmers in all concerned countries. They have encouraged the dissemination and adoption of these techniques via on-farm demonstration visits, or through presentations at conferences, seminars, meetings, etc. Farmers' groups, associations, cooperatives, and foundations have had a crucial role in these initiatives (in Brazil for instance **4.1**).



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A FEW KEY FIGURES ON DIRECT SEEDING

PIONEER FARMERS

- **USA:** Young, the first to implement direct seeding without tillage (Kentucky, 1961) in collaboration with S. Phillips, agronomist
- **Australia:** H.H. Tod (1974), N. Ronnefield (1980), G. Marshall, Neil Young (President of WANTFA, Western Australian No-Tillage Association)
- **Brazil:** H. Bartz (1972) associated with R. Derpsch (researcher, Southern Federal Agricultural Research Institute, now the *Instituto agronômico do Paraná*), M. Henrique Pereira, F. Dijkstra, H. Peeten
- **Argentina:** H. Ghio and H. Rosso (1975), J. Cazenave and C. Baumer (as of 1977)

AGRONOMISTS AND RESEARCHERS

- **USA:**
 - ◉ H.H. Bennett (father of soil conservation and Director of the Soil Conservation Service in the 1930s)
 - ◉ E. Faulkner (author of the *Plowman's folly*, 1943, denunciation of tillage and in favour of soil cover)
 - ◉ S. Phillips, (University of Kentucky as of 1961)
- **Australia:** J. Jones and L. Ward, pioneers of crop residue management in the 1980s (Soil Conservation Branch), and B. Crabtree (1990s)
- **Brazil:** R. Derpsch, T. Wiles, M. Ramos, W. Winche (ICI, agrochemical company), J. Landers, L. Séguy and S. Bouzinac (CIRAD)
- **Argentina:** M. Peretti and R. Fogante (1975), E. Lopez Mondo (1983) of the *Instituto Nacional de Tecnología Agropecuaria* (INTA)

CIRAD RESEARCH: DMC FOR SMALL-SCALE FARMING IN DEVELOPING COUNTRIES AND LARGE-SCALE MECHANIZED FARMING IN THE TROPICS

There is now global awareness on the fragility of our environment, as reflected in major international conventions (biodiversity, climate change, combating desertification). The situation is especially serious in developing countries where there is high population growth, land saturation and pressure on natural resources. Traditional agriculture is no longer able to preserve the fertility and production capacity of soils. It is thus essential to develop alternative solutions.

Direct seeding techniques developed in subtropical (Brazil) and temperate (USA, Australia, Argentina) areas and based only on crop residue are not sufficient to quickly and cost-effectively restore and then preserve overall soil fertility in tropical areas (crop residue mineralises much too quickly in hot regions). Hence, additional biomass in the form of plant cover is required. Based on this fact, research under way since the 1980s by CIRAD (L. Séguy and S. Bouzinac) and national partners (farmers, cooperatives, private companies, etc.) is aimed at creating new cropping systems based on the Brazilian experience on large-scale mechanized agriculture using direct seeding. The challenge was to adapt and disseminate these systems in all tropical ecoregions (no longer temperate and subtropical) for implementation on small-scale farms, which are generally poor, with no access to inputs and where soil erosion and degradation are severe. Cropping systems have been developed by CIRAD, i.e. DMCs, which combine direct seeding and permanent plant cover. They can be adapted to needs in all dry and humid tropical regions (Africa, Asia and tropical America). The aim is now to disseminate this new and truly sustainable farming method throughout the intertropical world. ■

AN ECONOMIC AND POLITICAL SETTING THAT TRIGGERED CHANGES IN FARMING PRACTICES

Some global economic and historical data have promoted direct seeding:

- The oil crisis in the 1970s led to a reduction in fertilizer use and fuel consumption.
- The reduction in herbicide and specialised farming equipment prices in the 1990s.
- The increased volatility in world commodity prices prompted some countries to diversify their agricultural production and crop rotations.



HISTORY OF DIRECT SEEDING WORLDWIDE

The direct seeding cropping system was created and widely disseminated. The area under direct seeding has been increasing at an incredible rate over the last 20 years (increase of 15% a year on average). This increase has mainly involved large-scale mechanized agriculture (especially in USA and Brazil). In 2005, direct seeding was practiced on around 95 million ha.



Key DMC principles

1.3



© K. Neaudin

What are the main agricultural principles underlying DMC?

DMCs MIRROR THE FUNCTION OF FOREST ECOSYSTEMS

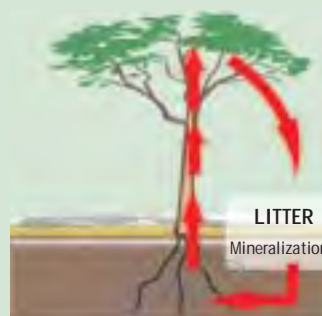
DMCs are designed to function like forest ecosystems, which are naturally stable, sustainable and based on high biological activity. This biological activity replaces mechanical tillage and enhances the soil structure, **nutrient recycling** and water management. These systems emulate the function of forests by promoting litter production and functioning in a closed circuit, without loss of material (chemical elements and soil) in deep horizons or on the surface, and with constant recycling between dead and live plant material. On a plot scale, DMCs are based on three key principles:

- **The soil is never tilled** and crops are sown by direct seeding.
- **Plant cover (dead or live)** provides permanent soil cover.
- **Crop sequences or rotations** are implemented in association with cover plants.

The technical conditions for DMC implementation vary markedly depending on the prevailing socioeconomic and agroenvironmental settings. No standard 'recipe' can thus be proposed, which would be too simplistic. However, some examples of DMC implementations are described here in Focus 3 (Cameroon [3.1](#), Laos [3.2](#), Madagascar [3.3](#) and Tunisia [3.4](#)).

PRINCIPLE 1: THE SOIL IS NEVER TILLED

When a soil is not tilled for several successive years, the more or less transformed biomass (crop residue and cover) accumulates to form a mulch layer that protects the soil against erosion and climatic variations (buffer effect). In DMCs, traditional ploughing is replaced by 'biological tillage' via the root systems, which create an environment that is highly favourable for fauna, which in turn 'biologically process the soil' (worms, termites, etc.). In untilled soil, this creates a suitable habitat for the development of various organisms, ranging from insects to bacteria and microscopic fungi. These organisms process, incorporate and mix the mulch into the soil and decompose the product to form humus. Fungi and soil microfauna (worms, etc), or so-called 'soil engineers', feed on organic matter lignin, which is then further degraded by bacteria. This macrofauna is also involved in the formation of aggregates and galleries (macropores) in the soil. This activity distributes the organic matter in different soil layers and mixes it with mineral matter derived from rock decomposition. Finally, the soil structure is improved and stabilised. Water infiltration is also facilitated, thus reducing runoff and risks of flooding during rain storms.



Ca, Mg, K,
NO₃, P...

Functioning of a forest ecosystem

Ca, Mg, K,
NO₃, P...

Source: CIRAD website
<http://agroecologie.cirad.fr>
From Séguy, Bouzinac, 1996.



SOIL MECHANISMS: SOIL FORMATION OR PEDOGENESIS

Soil is formed in three steps:

1. Physical disintegration and chemical alteration of bedrock.
2. Organic matter enrichment: soil is created when the organic constituents are derived from animal and plant organisms (organic matter) in addition to the mineral constituents. The decomposition of raw organic matter by soil microorganisms leads to the formation of CO₂ and a black substance (stable organic matter) called humus.
3. The migration of substances through the soil via water movements then determines how the soil evolves:
 - Downward movements include **leaching**.
 - Upward movements include upwelling.

The intensity of these movements depends on many factors: rainfall, humus content and nature, soil permeability, root system activity, etc.

SOIL FERTILITY—THE BASIS OF PLANT PRODUCTION

Soil fertility represents its production potential and depends on climatic and pedological factors. Humans play a key role in soil fertility by accelerating degradation (too intensive tillage techniques) or, conversely, enhancing it. Organic matter has an important role at this point by improving:

1. the physical qualities of the soil (humidity, aeration, temperature and compaction resistance) by stabilizing the soil structure and controlling humidity;
2. its chemical qualities (acidity, chemical composition) and thus the function of fixation mechanisms and exchange of nutrients between the soil and plants;
3. its biological qualities by supplying nutrients to living soilborne organisms and thus by activating microbial life that actively participates in plant nutrition.

(From Soltner, 1994)

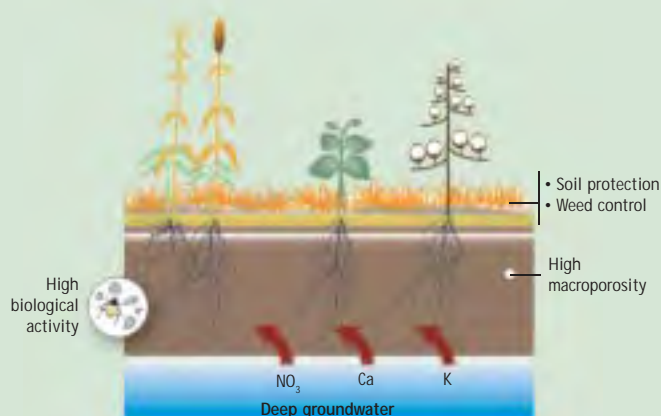
PRINCIPLE 2: THE SOIL IS PERMANENTLY COVERED BY PLANTS

Live or dead (straw) plant mulch provides permanent soil cover. Residue from the previous crop can be left on the soil or cover plants can be sown (**row or relay intercropping**). To avoid competition with the main crop, the cover is subsequently dried (mown, crushed or herbicide treated), kept alive or potentially controlled under the crop canopy by a low-dose herbicide treatment.

Then the biomass is left on the surface, not buried. Finally, seeds are sown directly in the residual plant cover after opening a hole or furrow with an adapted seeder (manual cane planter or stick). Cover plants are selected according to their complementarity with the main crop, their possible uses (food for humans or livestock), but especially their soil fertility enhancement potential. They are carefully selected to emulate the function of forest ecosystems—they must provide quick biomass production and have a root system that can reach deep groundwater supplies. These plants act as 'nutrient pumps':

- **Their powerful root systems help to structure the soil from the surface to deep horizons**, to avoid **compaction** and maintain **porosity** conditions that are favourable for all crops in rotations. These species, with different root systems, tap different deep soil horizons. Water infiltration and air circulation are improved (macroporosity), along with **water retention** in the smallest pores (microporosity).
- **Their root systems help to upwell and recycle nutrients** located in deep soil horizons so as to make them more accessible for the next crop. This function is essential to reduce nutrient loss from the cropped ecosystem (groundwater polluting nitrates, sulfates and bases), to improve depleted soils and make them more productive.

Cover plants are selected according to their ability to perform their agricultural functions even under harsh cropping conditions (low rainfall, highly acidic soils, etc.). Moreover, they promote the development of high biological activity throughout the year, thus gradually strengthening the physical, biological and chemical qualities of the soil. Some of these plants may be able to disintoxicate the soil (e.g. *Brachiaria* sp. reduces aluminium toxicity).



Cover plant functioning

Source: CIRAD Madagascar website (www.cirad.mg)



THREE TYPES OF PLANT COVER

The length of the rainy season and amount of rainfall are factors that determine which type of DMC that can be implemented:

- **In systems with permanent dead cover**, a cover plant with a high biomass production capacity, which is sown before or after the commercial crop, is used in addition to residue from the previous crop. This cover can be rolled or crushed with a tool, or dried with a nonselective herbicide immediately prior to direct seeding the commercial crop.
- **In systems with permanent live cover**, a forage plant is used as cover and only the above-ground part is dried with a contact herbicide prior to seeding the main crop. The underground vegetative reproductive organs are thus preserved so the system is continuously regenerated. The cropping system is managed such that the cover plant begins its normal growth cycle once the main crop has matured.
- **In mixed systems**, the commercial crop is followed by a cover crop (high value added edible crop grown with minimal inputs) and a forage catch crop. The two successive crops are harvested during the rainy season, followed by meat or milk production during the dry season thanks to the forage crop. A maximum amount of carbon is sequestered in the soil via this high phytomass production during the dry season.

(from Séguy *et al.*, 2001)

PRINCIPLE 3: CROP ROTATIONS

In addition to their nutrient pump role, rotations of various plant species diversify the soil flora and fauna. Their roots secrete different organic substances that attract a diverse range of bacteria and fungi. These microorganisms subsequently play an important role with respect to nutrient availability for the crops. Crop rotations are especially important for integrated pest management since they upset the pathological cycles.

Weeds are controlled through the effects of shade (competition for light) and/or allelopathic effects (competition between plants of different species via toxic substances excreted by the roots or leaves). Crop diversification also provides a range of different products (food for humans and livestock), thus enhancing economic stability. ■

Agricultural and environmental benefits of DMC

1.4



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How can environmental concerns be reconciled with agricultural production?

DMCs provide many environmental and agricultural benefits, some of which may be noted in the field and others that have an indirect impact on farmers. Some of these benefits are not yet clearly understood, especially those only perceptible when DMCs are implemented on a very large scale (an entire agrarian region, for instance) (boosting water table levels, etc.).

SOILS BETTER PROTECTED FROM EROSION



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Erosion (water, wind) is triggered by a combination of factors: slopes, climatic hazards, poor landuse, bare soils, etc. It is limited by the presence of live or dead plant cover and the absence of tillage. Plant cover decreases

the mechanical impact of raindrops on the soil and improves water infiltration, thus reducing runoff and soil loss. Decomposition of this cover by live soilborne organisms produces humus, which is essential for stabilising the soil structure (less compacted). Moreover, the presence of plant cover limits drying of the surface layer (better moisture and lower temperatures).

- ◇ **Effects on the plot scale:** *reduced runoff, better soil stability and fertility, better water management and efficiency*
- ◇ **Effects on the landscape unit scale:** *improved soil protection and fertility regeneration, better protection of downstream structures (dams, roads, etc.)*

ENHANCED SOIL STRUCTURE AND BIOLOGICAL ACTIVITY

Plant residue accumulation and no tillage leads to an increase in organic matter on the soil surface (0-10 cm), and then in deeper layers. The root systems of crops associated with cover plants, along with microorganisms and soil fauna, fulfil the soil tillage function and enhance the soil nutrient balance ('biological tillage'). Soil fauna (worms, arthropods, etc.) break down the organic matter, which is then degraded by microorganisms and transported to deeper and more stable soil horizons. In the most efficient DMCs, organic matter levels can thus be as high as in natural ecosystems, even when starting from highly degraded conditions, within a timeframe that is as short as that which led to their degradation!

EROSION AND RUNOFF—AN EXAMPLE FROM BRAZIL

Implementation of DMCs led to the preservation of 18 t/ha/year of soil, through:

- a 76% reduction in losses due to erosion in comparison to **conventional cropping systems**;
- a 69% reduction in runoff.

(From J. Landers, and the Associação de Plantio Directo no Cerrado, 2002, quoted in CIRAD, 2002)

Chemical products (pesticides and chemical fertilizers) should be rationally used to avoid altering the essential biological activity in the soil. Soils under DMCs are always protected from pollutants by the permanent litter cover. During biological digestion of this litter, intercepted polluting chemical molecules are degraded into simpler nonpolluting molecules. DMCs likely (studies under way) function as self-cleaning systems (soils and crops).

Cover plants with powerful root systems decompact the soil and restore sealed soils. They also **recycle nutrients** from deep soil layers. The choice of cover plants is crucial—the most efficient are strong and able to efficiently protect and restructure the soil, while recycling nutrients from deep layers (which requires water from deep horizons). The dry matter production capacity of the systems, even in the dry season, is thus increased as in forest ecosystems.

- ◇ **Effects on the plot scale:** *higher organic matter, nitrogen and carbon levels, recycling of minerals from deep soil horizons to the surface (input savings), enhanced soil structure and **porosity***
- ◇ **Effects on the landscape unit scale:** *regeneration of the fertility of even the most depleted soils, regulation of soil-water table moisture flows, biological quality of soils, water and crops*



Compacted soil



Noncompacted soil

© L. Séguin

REDUCTION IN DISEASE AND PEST PRESSURE

DMCs are based on integrated pest and disease control methods, i.e. crop rotations represent a key element of this new strategy to break the cycle of diseases and **weeds**. DMCs also improve crop nutrition regulation by avoiding losses via **leaching** to the water table and reducing excess soluble nitrogen and sugars in plant tissues, which are the main foods of pathogenic fungi and pests. The presence of permanent plant cover also helps control weeds (effect of shade and **allelopathy**). Pesticide treatments are also reduced.

- ◇ **Effects on the plot scale:** *reduced fertilizer and pesticide dosages (input savings)*
- ◇ **Effects on the landscape unit scale:** *reduced impact on soil pollution and the water table, enhanced food quality and security*

BETTER WATER MANAGEMENT

In dry climates, the soil is more humid under DMC (elimination of surface runoff, limited evaporation, increased **water retention capacity**). The roots of cover plants also capture deep moisture via their roots, thus improving the water balance. In wet climates, the greater infiltration and drainage in the soil enables quicker backflow of water to fields. This better water infiltration reduces flooding risks by storing high quantities of water in the soil and slowly releasing it to supply rivers. With DMCs, the soil is supportive, even under waterlogged conditions, so machinery has permanent access to fields without risk of compaction or accentuated deformation of the soil surface (reduction in production costs).

Better infiltration helps to replenish the water table. The effects of DMC adoption on water management on a larger scale, such as landscape units and catchment basins, are still not fully clarified. The geographical range of crops can be changed through modification and improvement of the water balance for crops in all soil-climate conditions. Hence, cotton with the highest productivity in the world under rainfed conditions is now cropped in wet tropical areas (Brazil, research of L. Séguy *et al.*); rainfed maize and rice can now be cropped in the Sudanian zone (northern Cameroon, research of K. Naudin **3.1**).

- ◇ **Effects on the plot scale:** *better water use and efficiency, reduced agricultural consumption*
- ◇ **Effects expected on the landscape unit, catchment basin, large ecoregional scale:** *reduced risk of flooding and destructive flows, preservation of water resources (quality and quantity), increasing downstream water table levels, extension of the geographical range of food and commercial crops.*



AGRICULTURE AND THE GREENHOUSE EFFECT

Agriculture is responsible for 30% of global greenhouse gas emissions, including 25% of CO₂ emissions and 70% of N₂O emissions.

(Source: FAO, 2001)

CONTRIBUTION TO BIODIVERSITY CONSERVATION **2.2**



© L. Séguy

Untilled fields with permanent plant cover provide an excellent habitat for living soilborne organisms, while protecting the soil from various phenomena (erosion, etc.) and increasing the available quantity of organic matter—the basis of the food chain. This plant cover

also provides physical protection for other species, which in turn attract insects, birds and other animals (however, this depends on the extent of crop protection treatments and their toxicity). Contrary to monocropping systems, genetic biodiversity is preserved and enhanced by diversifying crops, implementing rotations and using cover plants.

DMCs promote the settling of shifting agriculture (cause of 27% deforestation in tropical areas every year), thus indirectly preserving tropical forests by reducing deforestation. Moreover, DMCs are the only inexpensive currently available techniques that enable natural control of plant pests, such as *Striga* (which attacks cereal crops on degraded soils in Africa, Madagascar and Asia), that destroy crops and force local inhabitants to change regions and thus consume new natural resources.

- ◇ **Effects on the plot scale:** *increased biodiversity and agrobiodiversity (crop diversity)*
- ◇ **Effects expected on the large ecoregional scale:** *contributes to biodiversity preservation, reduction in shifting cultivation and deforestation, inexpensive natural control of crop pests.*

CARBON SEQUESTRATION AND REDUCTION IN THE GREENHOUSE EFFECT **2.3**

Storing carbon in the soil is an agricultural (enhanced physico-chemical and biological soil properties) and environmental (reduction in atmospheric CO₂) challenge. The increased atmospheric greenhouse gas (GHG) concentration contributes to global warming. It is now clearly established that agriculture is responsible for substantial GHG emissions and that this could be reduced by implementing cropping techniques like DMC. Agriculture can have a positive or negative impact on the greenhouse effect, i.e. as a GHG emitter in **conventional agriculture** and as a carbon sink. In DMC, the balance is markedly in favour of carbon sequestration. The use of direct seeding reduces fuel consumption (less mechanized work), thus reducing CO₂ emissions from tractors. DMCs also promote carbon fixation in organic matter accumulated in the soil—this carbon is literally trapped. Hence, by implementing DMCs, 0.5 to over 3 t/ha/year of carbon can be fixed over a period of at least 10 years. Large-scale implementation of DMCs can thus significantly contribute to controlling air pollution overall, while reducing global warming.

- ◇ **Effects on the plot scale:** *input savings (especially fuel), soil improvement*
- ◇ **Effects expected overall:** *better air quality, reduction in the greenhouse effect, thus reducing global warming. ■*

Economic benefits of DMC

1.5



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What are the economic benefits and costs of DMC on a field scale and globally?

The economic benefits of DMCs may be noted in the short term, e.g. reduced production costs, or in the long term, e.g. stabilized crop yields. They can be direct for farmers (reduced labour time) or indirect (reduced infrastructure maintenance expenses), and on different scales, i.e. from the farmer to the planet. The economic impact of DMC adoption depends on the features of the DMC system implemented and the local setting.

- In mechanized agriculture, direct mechanization costs (maintenance and machinery repair) are reduced. No sophisticated equipment is required (except for a special seeder in some cases), so DMCs can be adopted by even the poorest farmers. The fact that the number of cultivation operations is reduced means that there is less equipment degradation, and maintenance and repair expenditures are lower.

ON THE FARMER SCALE

REDUCTION IN PRODUCTION COSTS

- DMCs reduce labour time and laborious work, thus facilitating management of peak labour periods (field preparation, crop maintenance). The cropping calendar is more flexible, with a decrease in the number of cropping operations. This time and labour savings enables farmers to diversify their activities and increase their cropping area, and thus their income.
- In the long term, savings are achieved in inputs (fertilizers, pesticides, diesel fuel) as compared to conventional agriculture. Not tilling the fields generates substantial diesel fuel savings (up to 50% in mechanized agriculture). Pesticide treatment and fertilizer application costs are also lower, but these savings are measured in the long term. The soil organic matter content increases under DMC, thus improving soil fertility and water retention capacity. These factors improve the efficacy of fertilizers, thus leading to a reduction in fertilizer quantities used in the long term. Herbicide purchase costs are lower when the permanent soil cover and crop rotations effectively control weeds. Pest attacks are also reduced through the use of crop rotations and cover plants.

YIELDS COMPARABLE TO OR HIGHER THAN THOSE UNDER CONVENTIONAL AGRICULTURE

Using DMCs can gradually (and sustainably) generate yields comparable or even higher than those obtained under conventional agriculture after 2-3 years (installation phase). The enhanced soil properties and fertility lead to fewer yield variations. Production is less affected by climatic variations thanks to the plant cover (limiting evaporation, better moisture status, etc.). Increased yields mean increased income for farmers. Marginal land can also be cropped under DMC. The crop yields obtained depend, however, on how efficient the farmer manages DMC techniques.

AGRICULTURAL PRODUCTION DIVERSIFICATION

Crop associations, rotations and sequences boost food and commercial crop production. By benefiting from the forage function of crop residue and cover plants, associations with livestock production also enable farmers to diversify their incomes. This agricultural production diversification means that farmers are less vulnerable to natural hazards (climate, pest and disease problems) and market fluctuations for cash crops.



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CUMULATED ECONOMIC BENEFITS ON REGIONAL, NATIONAL AND GLOBAL SCALES

Farmers do not directly perceive some environmental advantages ^{1.4} whereas they are obvious at other scales. They are hard to evaluate in monetary terms, as they are generally nonmarket gains, e.g. more regular river flow, reduced erosion, increased biodiversity, higher water table levels, etc. Some can be readily observed and assessed, while others are likely or hypothetical. Very little quantitative data is currently available at these scales.

- **The better water regulation and lower runoff** noted under DMC is a major benefit with respect to protecting downstream structures (dams, roads, etc.), thus reducing maintenance costs. In North Africa, DMCs could reduce the need to build expensive structures for soil protection and restoration, water and soil conservation. In Tunisia, the decrease in erosion and runoff linked with DMC implementation should help to reduce silting of dams (restoration costs are around 0.1% of the GDP).
- **A rise in water table levels downstream** is expected because of the better water infiltration, thus providing a more regular flow to replenish wells and lowlands (improving rangelands and off-season vegetable crop yields). Water quality would also be improved, thus enhancing drinking water and fishing in rivers, etc. There would also be savings with respect to irrigation and drinking water treatment and availability.
- **DMC promotes biodiversity** ^{2.2}. This complex but important environmental DMC benefit is hard to evaluate in monetary terms because the effects of decreased or increased biodiversity are indirect, and the costs and benefits cannot currently be estimated.
- **DMC has a recognised role in carbon sequestration** ^{2.3}. The impact of large-scale adoption of DMC on the reduction of greenhouse gas emissions and global climate change is currently being assessed (fixation of 0.5-2 t/ha/year for 10-20 years).
- **Improved and more stable agricultural production** would enhance farmers' standard of living, which would in turn help in fight against poverty and hunger worldwide.

DMC IMPLEMENTATION COSTS

For farmers, costs associated with DMC practices involve:

- **Purchases of seed (cover plants)**, herbicides, equipment and its depreciation.
- **Costs associated with DMC training and dissemination**: knowledge on the agricultural and environmental aspects of DMC implementation is essential, along with other complex aspects (plant associations, herbicide use, etc.). For farmers, this means managing new techniques and obtaining suitable supplies and equipment.
- **Social costs**: it is important to not underestimate the cultural and traditional aspects, which are deeply engrained in societies that traditionally cultivate using tillage. DMC represents a radical change in farming practices and mindsets. Adoption of this new cropping system requires major changes in crop management sequences (in the fields) and in the organization and management of farms and agrarian regions (e.g. to better combine cropping and herding ^{4.1}, ^{4.2}).

The main community costs concern awareness campaigns, training, supervision and extension of DMCs. There are also external technical assistance costs and costs for rural services required for implementing DMCs under good dissemination conditions (credit, supplies, markets, etc.). ■

Scales	Expected benefits	Costs
Farmer	<ul style="list-style-type: none"> • Decreased peak working periods • Decreased labour • Increased and stabilised yields • Input savings • Production diversification • Increased number of effective days for performing cropping operations (field access) 	<ul style="list-style-type: none"> • Equipment purchases and depreciation • Purchasing cover plant seeds and herbicides • Training and apprenticeship • Association organization and operational costs
Regional and national	<ul style="list-style-type: none"> • Decreased food insecurity • Enhanced protection of catchment basins, downstream structures and coastal areas • Rise in water table levels • Better water quality and flow regulation • Switch from shifting, resource-consumptive agriculture to stable and sustainable agriculture • Biodiversity protection 	<ul style="list-style-type: none"> • Training, awareness, supervision, extension • External technical assistance • Followup research • Improvement of rural services
Global	<ul style="list-style-type: none"> • Participation in the fight against poverty • Participation in controlling the greenhouse effect • Biodiversity protection • Increased economic activity • Combating desertification 	

IN THE COTTON-GROWING AREA OF NORTHERN CAMEROON

Since 2001, more than 200 farmers have tested DMCs (CIRAD/SODECOTON collaboration) with cotton/cereal rotations. The results revealed: (i) higher cotton (mean +20%) and sorghum (mean +15%) yields on over half of the plots as compared to the check plot, (ii) better water percolation through the soil, (iii) lower labour times, and (iv) higher net income (cotton and sorghum). Herbicide and nitrogen costs were higher during the first three years (unless the cover plant was a legume).

(From Naudin and Balabare, 2005; Naudin and Balabare, 2006)

	DMC	Conventional agriculture
Net income (€/ha)	301	225
Work days per ha	101	109
Appreciation (€/work day)	3.53	2.28

Conservation agriculture terminology

1.6



➤➤➤ Different terms found in the literature

■ Conservation agriculture (CA)

This term, which has been promoted by FAO (Food and Agriculture Organization of the United Nations) since 2001, refers to cropping systems that comply with the three following basic principles: direct seeding, permanent cover (crop residue or cover plants) and crop rotation. This term is now becoming widely accepted, but its definition is not as specific as it was at the outset, when it closely mirrored DMC.

■ Biological or organic agriculture

This refers to agriculture without reliance on commercial synthetic chemical inputs (fertilisers, pesticides, etc.). Ploughing and repeated tillage is acceptable (usually not implemented), but DMC can be practiced.

■ Agrobiology

This term was used by CIRAD in the 1990s in reference to DMC. It is no longer used to avoid confusion with biological agriculture.

■ Agroecology

Agroecology is a science that concerns all soil protection and fertility enhancement techniques, while also being productive without substantial chemical input application. This strategy improves the natural functions of ecosystems and thus intensifies biological activity in the soil, to the benefit of farmers and sustainable agricultural production. This term encompasses DMC, biological agriculture, etc.

■ Direct seeding

Direct seeding is a cropping system in which the seed is sown directly in untilled soil. Only a small seed hole or furrow is opened. There can be plant cover (permanent or temporary, dead or live) or the ground may be left bare, but generally there is a layer of crop residue.

■ Direct seeding mulch-based cropping systems (DMC)

This concept was launched by CIRAD in 1999 in reference to cropping systems that include no tillage and permanent plant cover on the soil. The expression 'plant cover' refers to dead mulch (crop residue, cover plants or dead **weeds**) or live mulch associated with the crop.

■ Simplified cropping techniques (SCT)

This expression is used by the French farming community in reference to agriculture without tillage (or no-tillage techniques, NTT), but with scraping of the soil surface (**shallow ploughing** or **scarification**) to bury part of the crop residue, so the ground is generally left bare.

■ Conventional tillage

In USA, this term refers to all systems (with or without tillage) in which there is no more than 15% mulch cover (crop residue) after sowing. In France, these are traditional techniques with tillage.

■ Conservation tillage (CT)

This American term refers to systems in which at least 30% of the field is covered by crop residue when the crop is sown. In USA, this includes four tillage methods, with the first two being by far the most important:

- **No-tillage (direct seeding)**: without tillage.
- **Mulch tillage**: whereby tillage is carried out with chisel ploughs and discs (typically American, not available in Europe), with less than 15% of the crop residue buried after a single pass, i.e. most of the residue is left on the surface. The crop is sown under the mulch layer with a special seeder. There is no equivalent in France.
- **Ridge tillage**: permanent ridges are tilled, followed by direct seeding.
- **Strip tillage (or strip-till or zone-till)**: only single, relatively narrow strips are tilled, often with a rotary hoe, to facilitate soil warming in the spring (used especially in the Corn Belt).

■ No-tillage, no-till, zero-tillage, direct seeding, direct sowing, direct planting

All of these terms refer to systems without soil tillage, i.e. direct seeding, without specifying the soil cover conditions. In USA, at least 30% of the field is covered with crop residue (see below).

■ Reduced tillage

This American term refers to situations in which 15-30% of the ground is covered (crop residue) at the time of sowing. It is quite close to the current French SCT (TCS in French) concept and the former minimum tillage concept.

■ Minimum tillage

This term should be avoided because it is too vague. It has several meanings in USA, Canada and Australia, e.g. reduction in the number of equipment passes (during the 1960s), or exclusively surface scraping with or without crop residue (1970s). ■



*Conservation
agriculture*

DMC and global environmental issues

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Focus 2 covers potential impacts of DMCs on the current main global environmental issues that are the concern of major international conventions, i.e. climate change, desertification control and biodiversity. The aim is to understand how and why DMCs, when implemented on a large scale, could bring partial responses or solutions to these different issues. DMCs have not yet been adopted by smallholders throughout large enough areas, e.g. a watershed or entire region, to be able to quantify their different benefits, especially in developing countries...

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2.1 DMC, land degradation and desertification

Potential positive impacts of DMCs for combating soil degradation and desertification

2.2 DMC and biodiversity

Potential positive impacts of DMCs on biodiversity preservation

2.3 DMC, carbon sequestration and climate change

Potential positive impacts of DMCs on carbon sequestration and thus in controlling global warming

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• **Documents that have been published in *La gazette des SCV au Cirad*** can be obtained upon request from Michel Raunet (CIRAD), michel.raunet@cirad.fr



DMC, land degradation and desertification

2.1



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➤➤➤ Are DMCs beneficial for controlling soil degradation and especially desertification?

Soil degradation has become a major problem worldwide. Five to seven million ha of arable land disappears every year. Tropical soils are now especially threatened as a result of high population growth and pressure on resources. Traditional farming systems can no longer maintain the fertility and production capacity of soils. Two key aims of DMCs are to control soil degradation and regenerate already degraded soils.

SOIL DEGRADATION FACTORS



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Land degradation is induced by a combination of factors, e.g. the disappearance of natural vegetation cover, tillage, slopes, climatic hazards and overuse of resources (overgrazing, etc.). The main cause of cropland degradation is water and wind erosion, which

leads to considerable land loss, especially on bare soils and recently cleared land. Organic matter and most minerals that can be assimilated by plants are concentrated in the soil surface horizon, which is the most important layer for crops, and these are the first elements to disappear.

➤➤➤ WHAT IS SOIL DEGRADATION?

This involves deterioration of the soil's chemical, biological and physical properties:

- Negative annual organic matter balance, thus deterioration of the soil structure, the **water retention capacity**, nutrient absorption and release
- Reduction in biological activity (microorganisms, insects, worms, etc.)
- Soil acidification
- Decrease in nutrient reserves
- Salinization through poor irrigation and drainage
- Loss of the surface **horizon** through water and wind erosion



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(from Steiner, 1996)

➤➤➤ WHAT IS DESERTIFICATION?

The United Nations Convention to Combat Desertification, which was adopted in Paris in 1994 and ratified 10 years later by 190 countries, defines desertification as "*land desertification in arid, semiarid and dry subhumid areas resulting from several factors, including climatic variations and human activities.*"

(See the Convention site for further information: www.unccd.int)

DESERTIFICATION—A GLOBAL PROBLEM



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Desertification is a complex process involving many natural and human factors. It leads to a decline in land fertility and impoverishment of the communities living on it. This process concerns all agrosystems worldwide where the soil is utilized, including rangelands, cropland and natural areas. A third of humankind is affected by desertification.

Some specific features characterize desertification-affected areas:

- The soils are **fragile, poor and unproductive**. Their structure is unsuitable due to the extremely low organic matter content. The soil also has low **porosity** or is completely sealed close to the surface.
- **Water is a scarce uncertain resource**. Moreover, rather than percolating through the soil, most rainfall is lost via runoff, thus depriving crop plants, rangelands and natural vegetation of water supplies.
- **Severe climatic events are common**: short, irregular and violent rain storms, high temperatures.
- **Soils affected by desertification**, especially in Africa, have a deep water supply (more than 1 m below the surface), even in the dry season. Crop plant roots do not benefit from this water layer (surface sealing due to tillage, soil porosity clogged in the surface **horizons**).



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These features, combined overuse of the environment and resources by humans, often leads to irreversible deterioration of the soil and environment.

DMCs EFFECTIVE FOR CONTROLLING SOIL DEGRADATION



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- **Impact of DMCs on the soil structure:** live or dead plant cover provides efficient protection against different types of physical soil degradation by offsetting the force of droplets hitting the soil. It enhances infiltration of water into the soil, slows runoff and halts soil loss via water erosion. The soils are literally 'knitted together' by the cover plant roots. The presence of plant cover limits drying of the surface layer by stabilizing the soil moisture and reducing the temperature at the soil surface. It also keeps fine soil particles from being carried away by wind erosion. The fact that the soil is not tilled and is protected by plant cover reduces **compaction**, which adversely affects many soils under mechanized cropping conditions in intertropical regions.
- **Impact of DMCs on the physicochemical soil properties:** they improve the soil organic matter content and maintain it at a high level (production in the topmost 10 cm surface layer). Organic matter is a key physicochemical factor in the soil (structural stability, water storage, mineral elements, etc.). Mineral availability is improved in the soil (upwelling of minerals from deep horizons via plant cover root systems). Legume plants can be used to enhance **atmospheric nitrogen fixation**. Mineral loss is reduced due to a reduction in erosion, runoff, leaching and mineral **recycling**. The increase in nutrients from crop residue helps alleviate soil acidity problems.
- **Impact of DMCs on water storage in the soil:** water infiltration is better, soil moisture is preserved (reduced evaporation) and water quality is better. The soil storage capacity increases. The higher organic matter content enhances this **retention capacity**. Rooting is improved by increasing the soil **porosity** in deep horizons.
- **Impact of DMCs on biological activity in the soil:** cover plants create suitable temperature and humidity conditions and generate organic matter, thus providing an ideal habitat and conditions for the development of various living organisms, ranging from large insects to microscopic organisms. The vertical and horizontal galleries that these organisms dig help to improve the soil **porosity** and chemical features by decomposing fresh organic matter, leading to the release of minerals that can subsequently be assimilated by plants. They participate in the formation of humus (humification), which is a source of minerals for plants while also enhancing the physical structure of the soil.

The macrofauna (over 2 mm in size: insects, worms, etc.) also help to increase the soil porosity. The mesofauna (0.2-2 mm: collembola, mites, etc.) enhance the soil microstructure. The microfauna (under 0.2 mm: protozoans, nematodes) promote chemical transformations in the soil. The plant component, i.e. essentially microflora microorganisms (algae, fungi, actinomycetes, bacteria), is also crucial in soil mineralization and humification processes.

Factors that promote soil degradation	DMC impacts	Expected effects
Physical features of soils: <ul style="list-style-type: none"> • Structure (loam, clay or kaolinite) • Low organic matter content 	<ul style="list-style-type: none"> • Organic matter enrichment • Action of cover plant roots • Increased biological activity • Maintenance of suitable porosity 	<ul style="list-style-type: none"> • Enhanced structural stability • Regeneration of degraded soils
Heavy machinery movements, tillage under poor conditions (mechanical erosion, soil compaction)	<ul style="list-style-type: none"> • Limitation in the number of heavy machinery runs • Untilled soil • Firmer soil profile 	<ul style="list-style-type: none"> • Enhanced soil structure • Better field access for machinery
Violent winds, bare pulverized soil (wind erosion)	<ul style="list-style-type: none"> • Protection by plant cover 	<ul style="list-style-type: none"> • Control of soil loss and dust clouds
Violent rainfall, steep slopes, bare soil (water erosion)	<ul style="list-style-type: none"> • Reduction in the impact of rain droplets by the plant cover • Soil 'knitted together' • Increased infiltration 	<ul style="list-style-type: none"> • Reduced runoff and loss of water and soil

EFFECTS OF DMCs ON VILLAGE LAND, CATCHMENT AND LANDSCAPE SCALES

- In arid and semiarid areas, erosion, especially wind erosion, is a major cause of desertification and soil degradation. Reducing or even halting erosion should markedly improve desertification control.
- Indirectly, silting of upstream dams is slower and damage to other public infrastructures (roads, buildings, etc.) is reduced by DMC implementation. Complex and expensive erosion work (soil protection and restoration, and water and soil conservation) is no longer necessary on land cropped using DMCs, e.g. in North Africa and especially Tunisia.
- With the substantial reduction in runoff, areas upstream of landscapes, depressions, basins and lowlands, and areas under glaciers should no longer be hampered by flooding. Village lands and inhabited areas would thus be protected against sudden water inflows.
- The increased water infiltration in catchments should boost the water table. Village wells could then be less deep and not as susceptible to drying, lowlands would have a better and more regular water supply, thus enhancing rice growing, off-season market gardening and livestock watering conditions, and water flows would be regulated throughout the year. ■



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DMC and biodiversity

2.2

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►►► Could DMCs bridge the gap between agriculture and biodiversity conservation?

Biodiversity contributes in many ways to the development of human communities by providing various products (food, wood, etc.) and services (e.g. carbon fixation). In addition to the ecological benefits for the community, the economic value of biodiversity is currently being promoted. The fact that biodiversity is dwindling is acknowledged by most scientists and politicians worldwide, with human activities being singled out as the prime instigator of this decline. There has been an inevitable call for modifications in human activities, especially cropping practices.

BENEFICIAL IMPACTS OF DMCs ON BIODIVERSITY AT DIFFERENT LEVELS

DMCs contribute in many ways to the sustainability of farming systems by increasing faunal and floral diversity in the soil, while not diminishing crop yields. After a few years of DMC implementation, the beneficial impacts of these systems on biodiversity may be noted at different levels—from soilborne microorganisms to forests and even natural regions.

►►► BIODIVERSITY



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The term 'biodiversity' is a contraction of 'biological diversity'. According to the UN Convention on Biological Diversity, this refers to "the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species,

between species, and of ecosystems." Biodiversity functions at three main levels:

- **genetic diversity:** diversity of genes within a species
- **species diversity:** diversity between species
- **ecosystem diversity:** diversity at a higher organization level, i.e. the ecosystem, which includes the diversity of different sustainable processes and interactions between species, their habitats and the environment.

(for further information, see the Convention website at www.biodiv.org)

►►► SOIL FROM A MICROBIOLOGIST'S VIEWPOINT

*"The soil is a complex living material—even more complex than water or the atmosphere, which are relatively simple environments. You know, the soil is a minority environment on Earth, only 30 cm thick on average. This medium arose via the fusion of bedrock minerals with the organic surface environment—humus. [...] Within its 30 cm thickness, the soil hosts 80% of the living biomass on Earth. Moreover, in this very thin soil layer, there are many more living organisms than in any other global environment. This is not very apparent. It is a microbial community that has been neglected especially since it has no clear economic value... [...] Microbes are the basis of life. Plants could not nourish themselves without the help of these vectors. Human industries try to copy the work of microbes, but at a phenomenal energy cost. Soil bacteria **fix nitrogen** from the air to generate nitrates. This is free! Humans, on the other hand, use 10 t of petrol to fix a tonne of nitrogen—which is sold at a high price—while neglecting to mention that these chemical molecules are not sufficient to make soil. Farmers can make soil by hand. So obviously, it is in the industry's interest to replace the traditional French agriculture model... Organic or biodynamic farmers have soils that are much more active than soils cultivated by farmers using conventional methods. Living soils."*

(from Claude Bouguignon, 2003)

DMCs AND SOILBORNE BIODIVERSITY

Without tillage, permanent plant cover provides an excellent habitat for living soilborne organisms, thus protecting them against stress (erosion, etc.), and increasing the quantity of available organic matter. Moreover, the root systems of crop plants, cover plants and **weeds** generate nutrients and enable soilborne organisms to proliferate. Soil fauna can be classified in three different groups: macrofauna (size > 2 mm: insects, worms, etc.), mesofauna (0.2-2 mm: collembola, mites, etc.), microfauna (< 0.2 mm: protozoans, nematodes) and microflora (algae, fungi, bacteria, etc.). More of this fauna is found in fields managed by DMC than in those in which **conventional** practices are used (more species with larger populations), especially within the top 0-10 cm soil layer. The basis of the food chain is restored with this increase in biodiversity and enhancement of soil organism activities, which in turn benefit other species (birds, rodents, etc.) and the plant cover also provides them with physical protection.

DMC, GENETIC DIVERSITY AND AGROBIODIVERSITY



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Biodiversity components associated with food and agriculture are grouped under the term 'agrobiodiversity' (crop plants, domestic animals, etc.). Genetic resources, a reservoir of crop plant biodiversity, decline at an alarming rate and many potentially useful genes disappear as a result of the

specialization, uniformization and intensification of **conventional agriculture**. From a varietal standpoint, these genetic resources are better utilized by DMCs. In conventional agriculture systems, many varieties are considered to be susceptible to certain pests and are thus eliminated through selection, despite their other advantages (hardiness, low fertilizer requirements, etc.). They are actually much better protected or more tolerant under certain microenvironmental conditions created by DMCs. Many varieties are thus better adapted to DMCs and could thus be rehabilitated.

Crop diversification, rather than monoculture, is promoted on DMC farms, which means that DMCs utilize and create biodiversity. Crop rotations and diversification as well as mixed covers with combinations of different plants help to boost agrobiodiversity. Cover plants are highly varied and could be combined (legumes, grasses, crucifers, etc.). They thus have various complementary agricultural functions (biomass and fodder production, soil restructuring, allelopathic effects, specific nutrient **recycling**, neutralization of acidity or salinity, etc.). Crop protection treatments in DMC fields could hamper the increase in agrobiodiversity, so the use of these chemical products should be rationally managed.



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DMC, BIODIVERSITY IN TROPICAL FORESTS AND PROTECTED AREAS

Farmers in intertropical regions always practice **shifting slash-and-burn farming** in forest areas. Due to high land pressure, fallowing periods are now markedly reduced and thus not long enough to ensure forest and soil fertility restoration. This practice is also one of the main causes of deforestation in tropical regions (27% of areas deforested every year)—a major factor underlying biodiversity loss. DMCs can be implemented to combine agricultural production and soil-fertility restoration at the same site and over the same period, e.g. 'tropical gardens' along the eastern coast of Madagascar, where traditional annual crops, cash tree crops and diversified livestock production may be combined.

Widespread adoption of DMCs would promote the settlement of farmers who practice shifting agriculture, which would in turn save tropical forests and forest biodiversity. DMCs could also likely have the same positive impact in peripheral protected areas, i.e. a key issue for landless farming communities (especially in southern Africa). Conflicts between 'biodiversity reservoirs' and 'arable land reservoirs' are prevalent in these areas and DMCs could very likely provide an interesting alternative. DMC fields are more favourable for wildlife (birds, reptiles, mammals, etc.) due to the observed improvement in biodiversity and biological activity in soils and the physical protection provided by the plant cover. Moreover, low-input DMCs preserve aquatic fauna in ponds and streams (better water quality relative to **conventional agriculture**). ■

PESTS, WEEDS AND DISEASES VERSUS AGRICULTURAL PRODUCTION

Increased biodiversity could lead to an increase in pests and other harmful organisms: **weeds**, pathogens (viruses, bacteria, fungi), nematodes, termites, larvae, slugs, insects, etc. Low-input integrated pest management is a component of DMCs and even one of the reasons underlying their success—but it is also one of the main stumbling blocks! Certain pesticides may thus be used (at low dosages and diversified).

Dead or live cover plants facilitate weed control by blocking out light and thus hindering weed development. By **allelopathic** control, they release chemical substances which keep weeds from growing. It is, however, also important to ensure that these cover plants do not compete with the main crop! Crop rotations are an additional key to the success of DMCs as they can be implemented to break the pest-disease-weed cycle.

DMC, carbon sequestration and climate change

2.3



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How could farming practices curb global warming?

Global warming is under way and could increase in the future, with a concomitant negative impact worldwide. CO₂ is a major greenhouse gas. In application of the Kyoto Protocol, a strategy is required which combines low energy consumption, the use of low-carbon energy sources, and carbon sequestration. Agriculture-oriented countries could actively participate in reducing greenhouse gas emissions by implementing alternative cropping practices like DMCs that have a high carbon sequestration potential.

GREENHOUSE GAS EMISSION AND AGRICULTURAL ACTIVITIES



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The increase in the atmospheric concentration of greenhouse gases (CO₂, CH₄, N₂O, H₂O) is contributing to global warming—this mainly involves carbon dioxide (CO₂). The volume of CO₂ released into the atmosphere accounts for 50% of the greenhouse effect. However,

nitrogen oxides (NO and N₂O) also have a substantial impact because, at equal volume, the effect of N₂O is 200- to 300-fold greater than that of CO₂!

The extent of greenhouse gas emissions from agricultural activities and their potential reduction by agricultural practices are now documented. Agriculture is involved in the greenhouse effect at two levels, i.e. as a greenhouse gas emitter and as a carbon sink. Agricultural activities actually account for over 23% of total CO₂ emissions. Fuel combustion, livestock production effluents and nitrogen fertilizer applications in agriculture also increase nitrogen oxide release. Many agricultural activities thus have an impact on carbon sequestration or greenhouse gas emission: tillage, input management, fossil fuel combustion (machinery), livestock production, etc. All modifications in agricultural practices would thus alter the extent of carbon release and fixation.

SOILS AND VEGETATION: MAJOR CARBON SINKS

Carbon sequestration involves capturing carbon emitted by different sources (e.g. vehicles) and storing it in a sink (soil, vegetation, ocean, etc.). Plants represent the startpoint of the carbon cycle. Through photosynthesis, plants absorb atmospheric carbon (CO₂) and store it in their biomass (leaves, wood, roots, flowers and fruits). This organic matter nourishes **heterotrophic organisms** (consumers). Carbon (CO₂) is released into the atmosphere through the respiration of heterotrophic and **autotrophic** organisms.



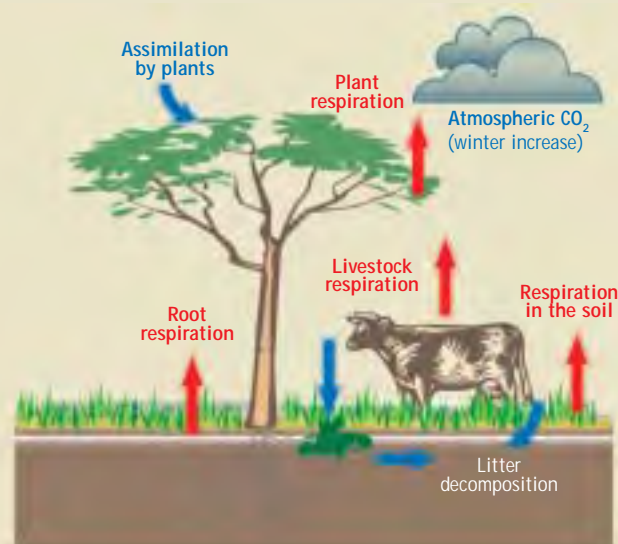
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The carbon balance should be mentioned when discussing carbon 'sinks'. Vegetation and soil are considered as carbon sinks when they fix (or accumulate) more carbon than they release. Storing carbon in the soil is therefore both an agricultural (improvement in the physicochemical soil properties) and environmental (reduction in

the quantity of atmospheric CO₂) challenge. Soils represent an enormous carbon sink. Globally, soils sequester more carbon (1,550 billion tonnes) than the atmosphere (750 billion tonnes) and plant biomass (550 billion tonnes) combined:

- **Soils under natural forests** contain the highest proportion of carbon, which is stored in humus (stable organic matter), roots, undecomposed litter on the soil surface and soilborne heterotrophic organisms.
- **Grasslands** also store high quantities of carbon, mainly in the soil.
- **Agricultural soils**, depending on how they are managed, can also act as carbon sinks, but are usually sources of atmospheric carbon. Various studies (CIRAD) have shown that the carbon sequestration potential of agricultural soils managed under DMC is around 1-2 t/ha/year of carbon over 10-15 years.

Carbon can thus be stored by changing landuse patterns (afforestation) or agricultural practices (no-till cultivation and permanent plant cover).



Carbon cycle

BENEFICIAL IMPACTS OF DMCs ON CARBON SEQUESTRATION



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Large-scale DMC implementation could substantially help to control air pollution, in general, and especially global warming. DMCs have several impacts on the CO₂ balance, i.e. by reducing emissions and especially carbon sequestration:

- DMCs eliminate tillage which is a major contributor to CO₂ release. In tropical agriculture, tillage accelerates organic matter decomposition (microbial mineralization) and thus carbon release. Under DMCs, agriculture becomes a net CO₂ storer and is no longer a net producer.
- DMCs decrease or even halt soil erosion, and thus the loss of carbon-fixing organic matter.
- DMCs markedly increase soil organic matter levels within a few years, therefore enabling carbon fixation in crop residue and cover plant derived organic matter accumulated in the soil. The quantity of carbon that can be sequestered is thus mainly dependent on the extent of increase in plant biomass and its nature (the higher the lignin content in the annually recycled harvest residue, the greater its involvement in reconstituting the humus stock).
- DMCs substantially reduce mechanized labour and thus fuel consumption. Tillage is the most energy consuming operation of all mechanized cropping operations. The use of DMCs, as compared to **conventional agriculture**, enables a significant decrease in fuel consumption and thus in CO₂ and CO emissions from tractors.
- Deforestation in tropical areas due to **shifting slash-and-burn agriculture** has a dual impact with respect to increasing the greenhouse effect, i.e. through the high C release triggered by biomass combustion during fires (100-200 t/ha C) and through the regular decrease in the organic matter levels in old forest soils transformed into tilled cropping soils. DMCs promote settling of roving farmers and thus indirectly participate in carbon sequestration.

- The impact of DMCs on soil fauna and flora richness and diversity should also be pointed out because these latter organisms can help to increase the soil storage capacity and diversification of transformation mechanisms.

In DMC soils, little is known about nitrogen oxide production during bacterial nitrification/denitrification processes, especially when legumes are used as cover plants. DMCs do not, however, seem to induce an increase in NO and N₂O emissions.

The carbon storage capacity of DMCs is of considerable environmental interest and could become a key objective within the framework of international discussions (commercial or not) on the greenhouse effect. ■



CALCULATING THE ECONOMIC IMPACT OF CARBON SEQUESTRATION UNDER DMC: A CASE STUDY IN TUNISIA



© J.F. Richard

The economic value of carbon sequestration can be estimated on the basis of carbon market prices, i.e. around US\$10/t (within the framework of the emission rights market established under the Kyoto Protocol). The World Bank

(2003) estimated the international damage cost at US\$20/t of released carbon. In Tunisia, DMCs enable the storage of 0.5 t of C/ha/year over 20 years, i.e. 10 t/ha. If 60% of the fertile land in this country were managed under DMC (3 million ha), DMC adoption would represent a non-updated international profit of US\$600 million over a 20 year period. Considering that a reduction of 40% of agricultural carbon emissions can be achieved under DMCs (CIRAD studies), that in 1994 this country released 2.6 tonnes of CO₂/capita/year and that there are around 10 million inhabitants, the total international profit would have been US\$21 million in 2003. Without updating, this would correspond to US\$462 million over 20 years!

(from Richard, 2004)



A FEW SIGNIFICANT FIGURES...

- In the Brazilian *cerrados*, studies (CIRAD) have highlighted a loss of 0.2-1.4 tonnes of C/ha/year under conventional agriculture systems in the 0-10 cm and 10-20 cm soil **horizons**. Conversely, under DMCs, the soil carbon content was found to increase from 0.83 to 2.4 tonnes of C/ha/year depending on the site, the type of system and cover species. Carbon stocks were first mainly boosted in the surface horizons.

- In Madagascar (Antsraibe region, Hautes Terres), studies have shown that C levels were significantly higher in the 0-5 and 5-10 cm layers under DMC as compared to conventional systems. However, no differences between these systems were noted below 10 cm depth. Annual C sequestration levels were higher in DMC systems (0.7-1.0 t of C/ha/year in the 0-20 cm layer), which was generally attributed to the high quantity of biomass recycled by these systems relative to systems with tillage.

(from Séguy et al., 2002; Razafimbelo, 2005)

3 DMC action research initiatives in different countries



The case studies in four developing countries presented in Focus 3 provide solid examples of successful DMC implementations in the transversal programme for monitoring and support, in line with CIRAD's action research. These examples are from areas with highly contrasted geomorphological, pedological, climatic and socioeconomic features, but which are all affected by serious erosion and land degradation problems. The four countries are representative of different regions, i.e. **Cameroon** (Central Africa), **Madagascar** (Indian Ocean and Southern Africa), **Laos** (Southeast Asia) and **Tunisia** (North Africa and the Mediterranean Basin).

CONTENTS

3.1 Cotton cropping systems in northern Cameroon

- a. Developing cereal-cotton based DMCs on dead plant cover
- b. Main impacts

3.2 DMC in Laos

- a. Developing a national agroecology programme
- b. Main impacts

3.3 DMC in Madagascar

- a. Developing agroecological techniques for various ecosystems
- b. Main impacts

3.4 Cereal based DMCs in northern Tunisia

- a. Developing cereal based DMCs on dead plant cover
- b. Main impacts

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3.1 Cotton cropping systems in northern Cameroon

a. Developing cereal-cotton based DMCs on dead plant cover

➤➤➤ How can DMCs be developed and set up on family smallholdings in semi-arid areas?

A PROJECT TO CURB SOIL DEGRADATION

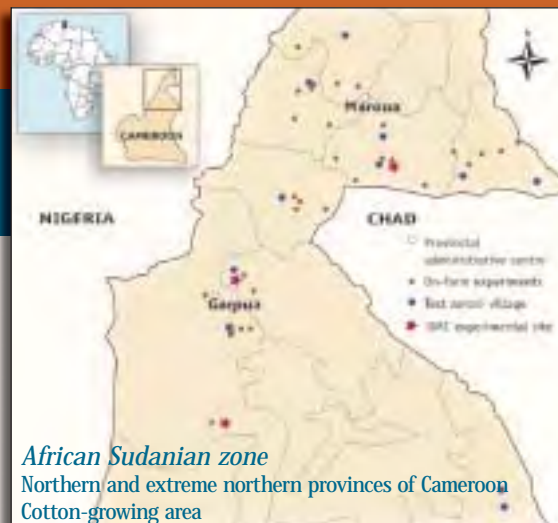
Population growth in northern Cameroon has led to increased cropping, deforestation and overgrazing. Fallowing times have decreased to nil in many areas, so soil fertility cannot be recovered. **Conventional cropping systems** based on sorghum and cotton involve tillage and no plant cover, thus leading to soil degradation and erosion. Runoff increases and already scarce water resources decline. The preservation and/or improvement of the fertility of cultivated soils is one of the main concerns of development agencies and farmers in these savanna areas.

In 2001, the first DMC trials were initiated in a research station (IRAD) and in experimenter farmers' fields under the supervision of the SODECOTON DPGT (*Développement Paysannal et Gestion de Terroir*) project, followed by the ESA (*Eau-Sol-Arbre*) project since 2002. It is implemented by SODECOTON, which is the main support structure for rural communities in the northern and extreme northern provinces of Cameroon.

Its aims are to:

- **adapt technical recommendations** from countries that are most advanced in terms of DMCs (Brazil, Madagascar);
- **demonstrate the agricultural, economic and environmental advantages of these systems** in northern Cameroonian conditions and their 'adaptability' to the local setting;
- **train local stakeholders** on these new techniques.

The experimental sites are located in the extreme northern province (long-standing cotton-cropping area) where the main issue is to regenerate the fertility of soils depleted by decades of almost continuous cropping and in the northern province (**newly cleared area**) where the aim is to preserve the fertility of more recently cultivated soils.



African Sudanian zone
Northern and extreme northern provinces of Cameroon
Cotton-growing area

From GSE Sabce Garoua



FEATURES OF THE AREA

Annual rainfall: low-600 mm in the north, 1 200 mm in the south

Soils: sandy-clayey tropical ferruginous

Topography: heterogeneous, vast plains and steep-sloped mountains

Natural vegetation: wooded and shrubby savannas

Population: over 3 million people, with variable densities (north: 20 inhabitants/km²; mountains: 200 inhabitants/km²)

Economy: small-scale family farming (2-3 ha farms) and livestock herding

Main crops: millet, sorghum, rice, cotton in rotations with cereals or cereals/legumes

Livestock herding: transhumant

Main constraints: frequent drought, short rainy season, serious erosion and runoff problems, degraded and generally compacted soils, low crop yields (cotton and cereals), overuse of resources (grazing), competition between herders and farmers for resources, low farmers' investment capacity, limited market access.

Partners: AFD/FFEM/CIRAD/SODECOTON (*Société de Développement du Coton au Cameroun*)/IRAD (*Institut de Recherche Agricole pour le Développement*)



Conventional system (cotton)

DMC (cotton)

The two plots are 5 m apart (northern Cameroon)

EXPERIMENTS CONDUCTED ON DIFFERENT SCALES

The research system is implemented on different levels:

- **In experimental plots.** These trials are conducted to produce scientific references on DMCs, to test new crop management sequences and train technicians and farmers on these techniques.
- **On farms.** DMCs are set up directly on farms and by the farmers so that they can test the potential of these techniques. Scientists may thus gain insight into farmers' opinions on these innovations. The network of experimenter farmers currently covers the entire spectrum of agroecological and human diversity of northern and extreme northern Cameroon.
- **In test terroirs (from 2004).** The aim is to determine the impact of introducing DMCs on village lands: relationships between farmers, herders and traditional authorities concerning land tenure; herd and land management by villagers, etc.

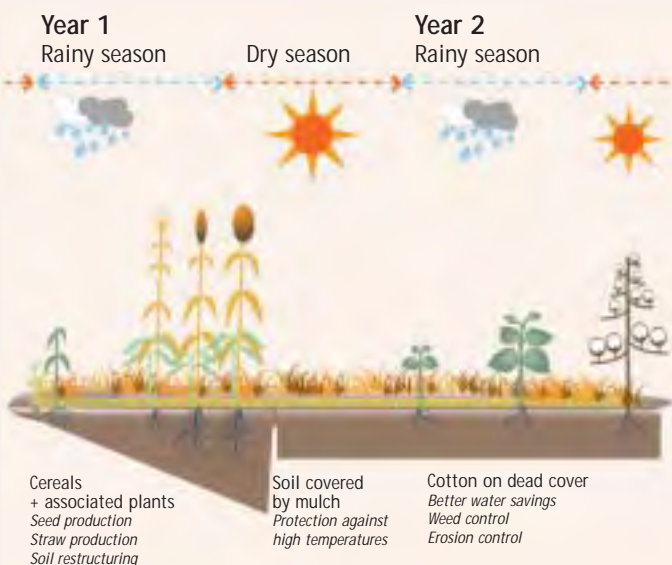
TWO TYPES OF DMC ARE TESTED

Cotton-cereal rotations are common on smallholdings in northern Cameroon. Two types of DMC on dead cover are tested on this basis:

- **Biomass production every other year:** in the first year, a cereal (sorghum/maize/millet) is cropped in association with a cover plant (legume or grass). These associations enable farmers to produce a high quantity of biomass on the plot, which is subsequently used as mulch (straw) the next year. The root systems also decompact the soil. The biomass produced in year 1 is left in the field or partially grazed by livestock during the dry season. It then provides soil cover for the cotton (*Gossypium* sp.) crop grown during the next rainy season.
- **Biomass production during the same year as the main crop:** the same cereal/cover plant association is conducted at the beginning of the rainy season in order to produce mulch. This is then mowed (and/or knocked down with a herbicide) after 2 months. It then provides soil cover for the subsequent cotton crop.

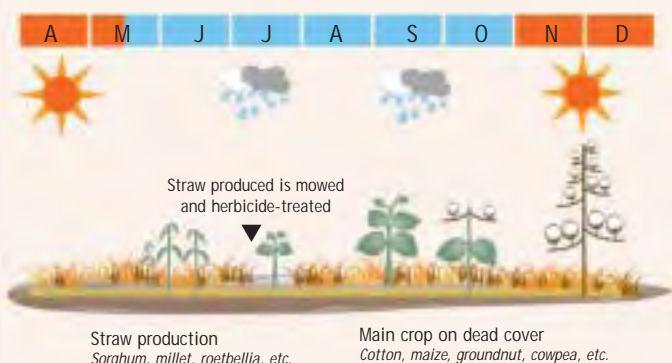
Maize is mainly grown in the northern province of Cameroon where it is rainy (900-1 110 mm/year), and sorghum is grown in the extreme northern province where there is less rain (700-900 mm/year). Millet is almost exclusively grown in specific regions like Mayo Danai (duck's beak).

Cereal- and cotton-based DMC in northern Cameroon



System 1: Biomass production every other year

Advantage: adapted to areas with low rainfall, corresponds to conventional cereal-cotton crop rotations
 Drawback: the vegetation cover must be protected if grazed by livestock



System 2: Biomass production during the same year as the main crop

Advantage: the plot does not have to be protected, as for system 1
 Drawback: requires a 6-month rainy season and herbicide treatments

▶▶▶ The main cover plants used in association with cereal crops in northern Cameroon (from Naudin, 2005)

Cover plants	Advantages	Drawbacks
<i>Crotalaria retusa</i>	<ul style="list-style-type: none"> • No protection required in the dry season • Seeds readily available • Marked physical soil improvement • Chemical soil improvement (nitrogen) • Weed control • Adapted to many environments 	<ul style="list-style-type: none"> • Low biomass production • Seeds have to be soaked in hot water to enhance emergence
<i>Brachiaria ruziziensis</i>	<ul style="list-style-type: none"> • Good straw production • Fodder production • Weed control (<i>Striga</i>) • Physical soil improvement • Deep rooting • Adapted to many environments • Termite resistant 	<ul style="list-style-type: none"> • Competition with cereal crops • Can deplete the soil if overgrazed • Emergence sometimes difficult • Low seed production • Requires dry season protection
<i>Mucuna pruriens</i>	<ul style="list-style-type: none"> • Chemical soil improvement (nitrogen) • High seed production • Good emergence • Good fodder production • Edible seeds (humans and animals) 	<ul style="list-style-type: none"> • Interrow congestion • Not well adapted for depleted and gravelly soils • Low biomass residue for mulch • Requires dry season protection
<i>Vigna unguiculata</i>	<ul style="list-style-type: none"> • Edible seeds • Good fodder production • Chemical soil improvement (nitrogen) • Adapted to many environments 	<ul style="list-style-type: none"> • Pesticide treatment required for seed production • "Fragile" biomass • Requires dry season protection
<i>Dolichos lablab</i>	<ul style="list-style-type: none"> • Good emergence • Good fodder production • Edible seeds (humans and animals) • Long growth cycle • Deep rooting • Adapted to many environments 	<ul style="list-style-type: none"> • Interrow congestion • Low biomass residue for mulch • Pesticide treatment required for seed production • Requires dry season protection

SELECTION AND USE OF MULTIPURPOSE COVER PLANTS

Cover plants (*Brachiaria ruziziensis*, *Mucuna pruriens*, *Dolichos lablab*, *Crotalaria retusa*, *Vigna unguiculata*) are selected on the basis of one or several traits: high biomass production for cover and livestock grazing, good drought resistance, rapid growth, good **nitrogen fixation**, good capacity for controlling invasive weeds, no competition with main crops, capacity to improve the structure of compacted soils, etc. In northern Cameroon, there are no ideal cover plants, whether or not they are adapted to environmental conditions and farmers' aims depends on their specific traits. Farmers choose these plants according to their adaptive traits. ■

3.1 Cotton cropping systems in northern Cameroon

b. Main impacts

Agricultural, environmental and economic benefits associated with DMC use were measured. These performance enhancements were generally visible after 3 years of DMC use, but less clear-cut during the first 2 years.

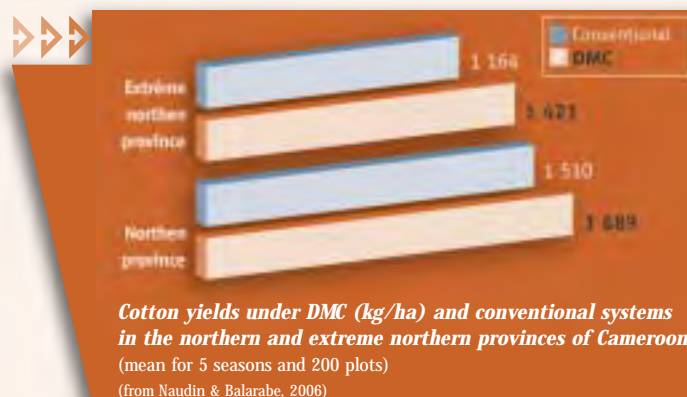
HIGH BIOMASS PRODUCTION VIA COVER PLANTS

Cover plants associated with cereal crops in year 1 produce mulch (straw) that serves as ground cover for the next cotton crop. These cover plants are sown between the cereal rows, sometimes increasing above-ground biomass production by twofold on the plot (e.g. *Brachiaria* associated with maize: total above-ground biomass increased from 2 601 to 5 423 kg/ha). This production must not be detrimental to the cereal crop, which in turn should produce at least as much biomass on DMC plots as on those managed by conventional agriculture.

BETTER RAINWATER INFILTRATION

With soil cover, moisture levels are maintained for a longer period on field plots, so cotton crops are less vulnerable during drought periods. Mulching can therefore have a spectacular impact, especially in the extreme northern province of Cameroon where the sparse rainfall is a limiting factor for cotton and other crops.

Soils naturally tend to form crusts, which can reduce infiltration of precious rainwater. This can be worsened by traditional cropping techniques that leave the ground bare at the onset of the rainy season. This phenomenon can be overcome by implementing DMCs, i.e. through the presence of plant cover and greater biological activity: 2% of rainfall is lost by runoff under DMCs as compared to 25% loss under conventional systems!



CONSISTENTLY HIGHER YIELDS AND BETTER QUALITY COTTON FIBRE

- **Cotton yields** were found to be higher after 3 years of DMC implementation, i.e. increasing from 12 to 22% as compared to conventional systems depending on the area. The differences were even more marked when the plot had been managed for a long time under DMC or when deficit rainfall conditions prevailed (extreme north). This was due to the higher available moisture in the soil because of mulching (higher infiltration, less evaporation, higher water supply). However, this difference depended on how the plots were managed, i.e. poor maintenance led to lower yields. The results seemed to indicate that the quality of the cotton fibre produced under DMCs was better than that obtained under conventional systems. The fact that water is available for cotton plants at the end of the growth cycle enhances fibre maturation.
- **Cereal seed yields** were also higher. After 2-3 years of cropping under DMC, most plots produced a twofold higher quantity of stems and leaves (e.g. sorghum associated with *Brachiaria*) while maintaining or increasing sorghum seed yields.

FEWER WEEDS AND PESTS

Weed infestation is lower on DMC plots than on conventional plots at all times during the cropping cycle. Mulch cover hampers weed growth and the elimination of tillage avoids turning up and stimulating weed seeds. Associations with cover plants generate good short-term weed control results since the cover plants compete with weeds. For instance, associating *Brachiaria ruziziensis* with cereals has a dramatic effect on reducing infestations of the cereal pest *Striga hermontica*.

MORE DIVERSIFIED SOILBORNE FAUNA

The diversity of animal species and their abundance above the soil, in the litter and soil were found to be higher after 3 years of DMC use. There were more invertebrates: 47 invertebrate families were identified (spiders, sowbugs, earthworms, etc.). This biodiversity is not detrimental to the cotton crop because the proportion of pest organisms relative to others remains steady or decreases under DMC. The biodiversity on the plot is higher on plots that have been managed under DMC for long periods.

POSITIVE ECONOMIC IMPACTS: INCOME, WORKING TIME AND HARD LABOUR

In 2004, the economic indicators measured highlighted a clear improvement due to DMC use as compared to conventional farming:

- Lower labour time and manpower (101 man-days/ha vs 109)
- Less laborious work (tillage and weeding eliminated)
- Higher net income (€301/ha vs 225, or €3.5/working day vs 2.3)

With DMCs, supplementary labour is required for sowing cover plants and manual weeding (instead of mechanical weeding). Manual weeding is laborious work. However, glyphosate spraying treatments using herbicide sprayers with caches provides a simple inexpensive solution that can be gradually adopted by farmers (spot spraying). In parallel, as the weed pressure is lower, manual weeding is reduced (with sufficient mulch cover). Moreover, tillage and **ridging** are eliminated—so the labour input is balanced out. A clear reduction in labour time is noted only after 2-3 years of DMC implementation.

The potential application of herbicides (only if the mulch cover is insufficient) and urea (50 kg/ha) represent supplementary expenditures. These costs are eliminated after several years of DMC use (no urea applications) and efficient plot management (additional herbicide treatments are unnecessary if mulching is sufficient).

QUICK ADAPTATION AND DISSEMINATION OF DMC BY FARMERS—“LEARN BY DOING”

An increasing number of farmers want to test DMCs in their fields: 17 farmers in 2001, 205 in 2005! Farmers are attracted by the different advantages of DMCs. It is essential to conduct on-farm experiments in order to train farmers on these techniques and get their immediate opinions concerning these innovations so as to be able to quickly improve them when necessary. Problems that arise are usually associated with poor DMC management. Farmers get a broad range of benefits.

 *Farmers' comments on DMC*
(from Naudin *et al.*, 2003 ; Naudin & Balarabe, 2004)

Advantages

- Reduced labour (no tillage and less weeding), less hard labour
- Production: better emergence and growth, more cotton bolls that are larger and more mature
- Water: the soil stays moist longer
- Fertility: less erosion, enhanced fertility, “the soil turns black”
- Fewer weeds

Drawbacks

- Straw: harvesting, storage, transport, mulching
- **Weeds:** control if mulching is insufficient (manual weeding harder), herbicide spraying costs
- Cotton growth and development: temporary nitrogen deficiency, pests in the mulch, waterlogged soil
- Termite infestation in plots



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HERDING SHOULD NOT BE OVERLOOKED IN THE NORTHERN CAMEROONIAN SOCIAL SETTING

The large livestock population in northern Cameroon is due to the high natural rangeland resources and agricultural by-products available. The herd size is increasing but the rangeland area is decreasing, thus prompting landuse conflicts between farmers and herders. In the social setting of northern Cameroon, grazing rights still apply, whereby herders are allowed graze their animals in rangelands and on all post-harvest crop residue.

This community management of grazing resources is a handicap to DMC implementation, despite the fact that grazing is possible under this innovative system. It is thus essential to collaborate with herders so that they can boost their fodder resources and be less dependant on crop residue. Various technical options are possible:

- Producing more biomass on crop plots using forage cover plants;
- Controlling access to biomass produced on plots by growing quickset hedges;
- Proposing plants to farmers and herders that will boost biomass production outside of the crop plots (*Stylosanthes* sp., *Andropogon* sp., etc.), i.e. along the edges of crop fields or in rangelands to enhance grazings;
- Proposing systems that do not require dry season protection of crop residue, e.g. producing biomass just prior to the crop (2nd type of DMC);
- Proposing systems in which the associated cover plant is not grazed by livestock (*Crotalaria retusa*).

The DMC adaptation phase will now begin on village lands in five representative areas with the aim of sustainably integrating herding with DMCs in the northern Cameroonian setting. ■



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System with tillage—maize without an associated cover plant: striga present



DMC—maize associated with *Brachiaria*: very little striga present

3.2 DMC in Laos

a. Developing a national agroecology programme

How can DMCs be developed and disseminated in smallholder rice-growing systems in Southeast Asia?

TWO RICE-GROWING AREAS—XAYABURY AND XIENG KHOUANG PROVINCES

In Laos, rice growing is by far the dominant crop. Laotian cropping systems have changed considerably over the last 15 years as a result of many factors:

- In **isolated mountain areas**, traditional farming systems with long fallows are now increasingly weakened by the population boom combined with the fact that land allocated to families is often insufficient.
- In **Mekong corridor areas** (especially in southern Xayabury province), which benefits from the best market access conditions (plain region), there has been a shift from traditional **slash-and-burn cropping** to more intensive agriculture with heavy use of inputs and mechanization. Massive environmental degradation is currently under way with serious economic, social and political consequences.

Two provinces in central and northern Laos reflect problems concerning mountain agriculture (Xieng Khouang province) and commercial agriculture of the Mekong corridor (southern Xayabury province):

- In **Xieng Khouang province**, the efficiency of traditional cropping systems (rainfed rice in rotations with long fallows) has been threatened as a result of increasing population densities and recent political strategies such as the national land allocation programme (1995). The aim of this programme was to limit slash-and-burn practices in favour of settled farming without fallows, but this gave rise to serious problems—allocation of too small and poor quality pieces of land (lowland rain-fed agriculture), high pressure on natural resources, etc. The excessively short fallow periods, due to the acceleration of rotations, is now weakening cropping ecosystems and also leading to the degradation of downstream rice infrastructures and roads.



From CIRAD



FEATURES OF THE AREA

Annual rainfall: mean 1 100-1 600 mm/year

Soils: highly diversified, with units on sandstone and claystone, intrusive basic rock, granite and schist

Topography: hills and medium mountains (400-1 400 m elevation)

Natural vegetation: humid tropical forests and savannas (Xieng Khouang province)

Population: 5.5 million people (mean 25 inhabitants/km²)

Economy: small-scale family farming (0.4-4.0 ha, mechanized, draught and manual agriculture)

Main crops: rice (rain-fed, lowland and irrigated), cash crops (maize, groundnut, Vigna umbellata, Job's tears, sesame, etc.), perennial crops (coffee, tea, rubber, etc.)

Livestock production: pigs, poultry, cattle, bubaline

Main constraints: soil erosion and degradation, decreased crop yields, chemical soil pollution, increased population pressure, insufficient land allocation per family (mountain area), rural poverty, need for an alternative to slash-and-burn agriculture

Partners: AFD/MAEE/FFEM/ Committee for Planning and Cooperation (CPC)/Ministry of Agriculture and Forest/National Agriculture and Forestry Research Institute (NAFRI)/CIRAD/ National Agroecology Programme (PRONAE)/ Point d'Application du Sud de la Province de Sayaboury (PASS-PCADR).



© F. Tivet

- **Southern Xayabury province** oriented its agricultural production towards commercial export crops (maize, sesame, etc.) following its integration in Thai domestic markets. This economic boom, accompanied by an increase in technology transfer from Thailand, has led to an increase in heavy mechanization and tillage with disc ploughs on sloped plots, which has caused erosion and rapid degradation of soils that were initially exceptionally fertile. Due to the high production costs of this mechanized agriculture, the degradation of downstream rice infrastructures and roads, along with declining yields, many farmers are currently trying to give up this heavy mechanization in favour of herbicide treatments to prepare their plots. The use of these inputs is, however, poorly controlled and a risk for human health and the natural environment.

LAOS IS STRIVING TO IMPLEMENT AGROECOLOGICAL STRATEGIES AND DMCs

The research part (NAFRI-CIRAD) of the Xayabury Rural Development Project (PRODESSA) was thus initiated in 2000 with the aim of introducing and disseminating agroecological techniques in this province where there was substantial soil erosion and degradation. Activities already initiated at Xayabury were then extended to Xieng Khouang province in 2003 with the launching of the National Agroecology Programme (PRONAE), that was designed to come up with alternatives to cropping systems in mountain regions (assarting) and in the Mekong corridor. PRONAE will ultimately:

- **propose policy-makers cropping systems as an alternative** to tillage (Xayabury) and slash-and-burn (Xieng Khouang) systems in order to enhance agricultural sustainability while preserving the environment;
- **promote their transfer** to development stakeholders and communities.

A ministerial council memorandum and a Ministry of Agriculture and Forestry decree were also put forward in 2005 to promote DMC as a national agroecological system and to integrate agroecological principles in national agricultural school curricula.

ADOPTION OF A SYSTEM APPROACH TO BENEFIT RURAL COMMUNITIES

The **system approach** adopted to promote agroecological systems involves different study modules and scales:

- **In the two provinces**, a diagnostic analysis was carried out to assess the environment at different levels (agronomic, socioeconomic, etc.).
- **Implementation sites** pool the diversity of cropping systems and the physical environment in each province. They aim to analyse conditions for implementing different types of DMC, broaden the technical options (diversification) and create an environment for professional training of all concerned stakeholders. An experimental system was also set up at the Agricultural Research Centre (ARC) in order to promote exchanges with NAFRI teams and the Nabong University of Agriculture.
- **An agrarian region scale validation network**, first small farmer-herder discussion groups (currently 36 groups, or 297 families) were set up to adapt, validate and define DMC adoption conditions. These new cropping systems should then be validated on an agrarian region scale in order to integrate collective land management, supply and marketing networks, cropping strategies and DMC integration.

This group organization facilitates transfers between the different stakeholders. Professional training tailored for agronomists, farmers-researchers and all development partners has also been set up. PRONAE and PASS have developed a partnership framework to streamline their operations and benefit maximally from complementary interventions (development-oriented research).

PASS disseminated the first systems proposed by PRONAE in 21 villages (385 families, 400 ha, 2006 cropping season). This dissemination was facilitated by the acquisition of equipment specifically adapted to direct seeding cropping systems.

INTRODUCTION OF CROPPING SYSTEMS AS AN ALTERNATIVE TO TILLAGE (XAYABURY) AND SLASH-AND-BURN (XIENG KHOUANG) SYSTEMS

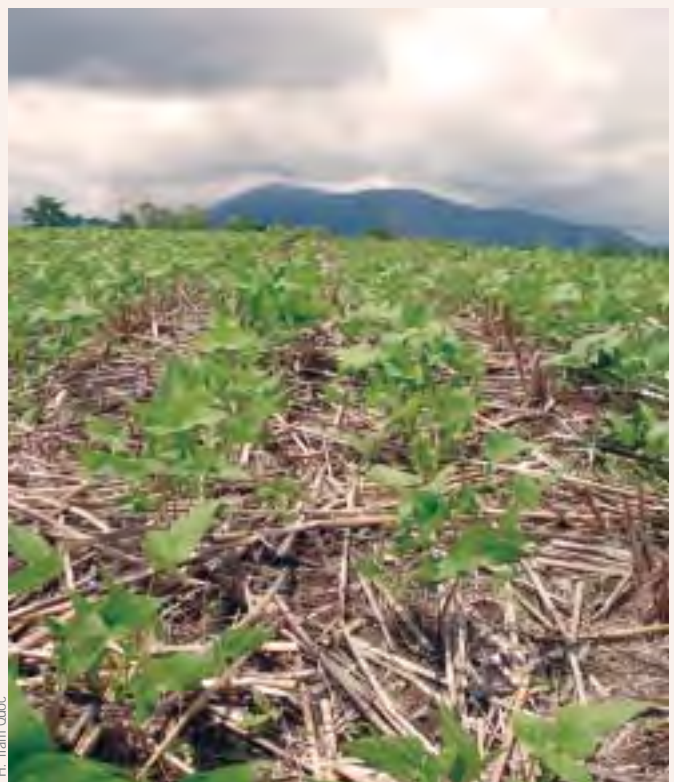
■ Commercial agriculture in the Mekong corridor

The first DMCs developed on the basis of traditional cropping practices in this area (Job's tears, *Vigna umbellata* and maize), with crop residue management, are currently being disseminated. New alternatives involving the use of cover plants and enhanced integration between farming systems (cropping, livestock production, perennial crops) are also being proposed.

■ Mountain agriculture

Depending on the initial situation, three approaches provide an alternative to slash-and-burn cropping:

- **To preserve the initial soil fertility:** manual clearing without burning, associated with simultaneous planting of **nitrogen-fixing** legumes, maintains the original physical and biological potential of the soil, while improving its initial mineralizable nitrogen content.
- **To preserve the soil production potential:** when fallows have been burnt after clearing, the soil must be covered by plants that protect the soil and yield supplementary off-season produce (fodder, seeds). These species are then used as mulch in which food crops are sown.
- **To restore the production potential of the soil:** the fallow period must be reduced by using plants with a high regenerating power while also producing seeds and fodder resources. This soil production potential restoration period can be applied as early as the first year by planting tubers such as cassava in association with *Brachiaria* species and legumes (*S. guianensis*). In the second year, the plot is subdivided, with half used for forage and the other half cropped with rice associated with cover plants. ■



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3.2 DMC in Laos

b. Main impacts

In addition to developing cropping systems as an alternative to traditional tillage and slash-and-burn systems, DMCs provide responses to major issues in Laos, e.g. growing rice under poor water management conditions, growing crops on uncultivated land, etc. They also provide a practical response to different constraints identified by farmers, e.g. high production costs, heavy labour, marked soil degradation, decreasing yields, etc. Constraints to their adoption must be taken into account to facilitate their large-scale dissemination, e.g. credit access, production resources, collective regulations, land-use rights, etc.

USE OF HIGHLAND PLAINS

In Xieng Khouang province, large grassy savannas and pine forests on highland plains (800 and 1 100 m) have only been slightly developed for agriculture and herding (extensive livestock production and rice development). The initially poor soils are regenerated at low cost by the following techniques:

- **Planting forage species** in rotation with food crops and/or commercial crops so as to restructure the soil.
- **Soil burning (or 'smouldering')**, followed by growing diversified direct-seeded crops in rotations in order to release many minerals in the soil and thus improve the chemical properties of the soil.

IMPROVING RICE FIELDS WITH POORLY MANAGED IRRIGATION



The cost-effectiveness of rice plantations is hampered by high initial expenditures and rehabilitation costs, in addition to low rice yields (under 3 t/ha). Alternative rice-cropping systems have been tested. The rice fields are improved by combining highly adaptable (different thermal, hydric and trophic conditions) rice varieties with DMCs. Problems concerning lowland rice and

highland rain-fed rice mainly concern Xieng Khouang province. Mixed rice varieties (programme of Séguy, Bouzinac and Taillebois, CIRAD) and Malagasy highland rice varieties are being assessed in different areas (highland plateau, collapsed depression, mountain farms).

CROP DIVERSIFICATION AND AGRICULTURE–HERDING–TREE INTEGRATION

The enhancement of labour and soil productivity via DMCs has given rise to new prospects concerning crop diversification and agriculture–herding–tree integration. This diversification involves the use of multipurpose cover plants that yield high quality crops (forage and seeds) during the rainy or dry season. This increased diversification is a key to DMC adoption. Seed production (mixed rice, legume food crops, forage, multipurpose plants, e.g. sorghum, finger millet, etc.) is crucial to ensure successful adoption of these species by communities and large-scale extension.

ECONOMIC IMPACTS FOR FARMERS—AN EXAMPLE IN XAYABURY PROVINCE



Using DMCs will quickly restore the production potential of the soil at low cost. They help to save on inputs and labour. The results obtained in Xayabury province revealed a marked reduction in production costs and labour time, and an increase in net margins (difference between the selling price and production cost) and labour efficiency:

- **The introduction of small-scale agricultural mechanization** (seeders and sprayers) has quickly overcome the first constraints to implementing DMCs on crop residue. For instance, for a field preparation method involving pre-emergence herbicide applications, the use of low volume spraying **nozzles** reduces the water flow rate to 100-150 l/ha (as compared to 600-1 000 l/ha with **conventional systems**). Heavy labour is also substantially reduced. Sowing maize with a digging stick takes 16 days/ha, and 4 days/ha with a planting dibble. The use of seeders (two row) with power-driven cultivators reduces this labour time to 4 h/ha and to only 1 h 15 min with four-row seeders (tractor).
- **Maize is the key crop of cropping systems in southern Xayabury.** For maize cropping, with crop residue management and under different soil-climate conditions, labour efficiency increases from 25 to 85%. It generally ranges from US\$2-4/day (net margin US\$300/ha) for the most efficient systems. On excellent soils without chemical fertilisation, maize yields can be boosted by over 15% in the first year. If this first step, which is based on crop residue management, generates interesting agro-economic results, then crop diversification should be immediately promoted, along with the use of multipurpose plants to reinforce these systems (diversification, erosion stopped completely, weed control, etc.).

CONSTRAINTS TO LARGE-SCALE DMC DISSEMINATION

Alternative cropping systems, which are currently based on crop residue management, were proposed to farmers. They are very promising as part of a gradual apprenticeship and adoption process. However, it is important to increase the technological options in order to meet farmers' multiple and varied demand (especially by developing systems that integrate multipurpose species to ensure permanent soil protection and integrated pest and weed management, while improving diversification). Moreover, considering the extent of cropland soil degradation, it is now urgent to implement such systems as soon as possible. The challenges to the widespread adoption of these practices are as follows:

- **Land allocation:** with collective land development projects, individual or collective land appropriation, and thus the use of potential developed land, is an important issue. The fact that insufficient land is allocated in mountain farming areas is a major problem with respect to natural resource management and cultivated soil protection.
- **Community management of plant cover:** better 'agriculture-herding-natural area' integration should be promoted to ensure rational use of crop residue and plant cover as forage. The agrosocioeconomic benefits of DMCs should prompt communities to draw up collective regulations to protect plant cover (straying herds, bush fires, etc.).
- **Credit access:** farmers claim that the lack of credit is a major constraint to access to technical innovations. This support is thus necessary and should be programmed in villages where projects are under way. The forms of this credit could vary, e.g. seeds, inputs and mechanization.
- **Mechanization access:** this should be promoted to facilitate extension of these new systems. Specific seeding and spraying tools are required. They should meet needs on different cultivation scales, e.g. manual, power-driven cultivator, 'heavy' mechanization, so that farmers will not be dependent on service providers.
- **Access to plant material and inputs:** the plant material should be available in each village so that it can be readily multiplied by farmers. Production of these species should be autonomous within agrarian regions. For input supplies, interventions are possible at several levels: informing sellers on required inputs; instructing sellers and farmers on how to use the inputs; encouraging specialised companies to manufacture specialised agricultural equipment.

Advantages and drawbacks of DMC—farmers viewpoints (From Tivet, 2005 ; Hoà Tran Quoc *et al.*, 2006)

Advantages

- Low production costs
- Quick field preparation
- Decreased erosion
- Increased soil fertility
- Increased soil moisture
- Weed control

Drawbacks

- Labour time and hard labour (without specific tools) for field preparation, thus limiting the area devoted to direct seeding
- Access to inputs and funds (lack of cash flow and/or microcredit)
- Lack of specific tools
- Technical skills required
- Cropping calendar flexibility
- Pest pressure (rodents and insects)
- Intoxication risks during herbicide applications

TRAINING ESSENTIAL FOR ALL DMC DISSEMINATION STAKEHOLDERS



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Farmers, scientists, extension agents, teachers, decision-makers and the private sector should be trained on these new cropping systems in order to enable their large-scale dissemination and appropriation by end-users. Training modules are already being used to train different local stakeholders:

- **Permanent modules** developed for farmers with some periods devoted to field training and exchanges between farmers to determine the conditions for DMC adoption and collective decision-making. In 2005, over 1 000 farmers attended field training sessions.
- **Medium-term training (9 months)**, is also offered within the framework of courses at the University of Agriculture and Forestry.
- **Training and awareness sessions** for decision-makers, extension agents and sellers.

Training of all of these stakeholders is also required on a national level, while improving relationships between stakeholders and knowledge transfers between stakeholders, who should be involved from the outset. Continuous support is required during the first seasons and it is essential to focus operations in specific areas where human, technical and financial resources are available, thus ensuring control of the technical guidelines. ■



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3.3 DMC in Madagascar

a. Developing agroecological techniques for various ecosystems

▶▶▶ How can diversified technological options be developed and disseminated for small-scale family farming in a highly contrasted environment?

MADAGASCAR, A LAND OF ECOLOGICAL AND HUMAN CONTRASTS

Madagascar is a land of contrasts with a unique spectrum of populations, climates and agrarian regions, where temperate tropical humid and dry and even Sahelian ecosystems are found.

Four different regions are representative of this ecological and human diversity:

- **Southeast**, hot and rainy;
- **Highland plateaus**, under a temperate highland climate;
- **Southwest**, under a semi-arid climate;
- **Alaoatra Lake and the Midwest**, with medium elevation ecological conditions and a long dry season.

Fighting rural poverty is one of the main challenges in Madagascar (over 80% of the population works in the agricultural sector), along with the protection of land and natural resources. Agricultural production, especially rice, no longer fulfils the needs of a growing population. The production of rice, the main crop in Madagascar, has not increased for more than 10 years. This has led to increased cropping in catchment basins and hills where soils are fragile and degrade easily. Soil erosion and runoff thus induce damage to downstream infrastructures.

INTRODUCTION OF AGROECOLOGICAL TECHNIQUES TO CONTROL LAND DEGRADATION

The first DMC tests conducted in Madagascar in 1990 were inspired by the Brazilian experience (L. Ségué, CIRAD), beginning in the highland plains region (Antsirabe). With the founding of the NGO TAFE in 1994, test areas for developing DMC-based cropping systems gradually expanded: in the southwest (Tuléar and Morondava), midwest (Alaoatra Lake) and southeast from 1998 (AFD-funded "Dissemination of agrobiological soil management systems and cropping systems in Madagascar" project). TAFE, with the support of CIRAD, has developed a broad range of DMC systems.

A national network of institutions (GSDM) was created to coordinate agroecological initiatives and promote technological options adapted to the main ecological conditions on the island. This overall setup was maintained from 2001 to 2003 despite the political and economic crisis affecting the country. Since January 2004, the Ministry of Agriculture, Livestock and Fisheries delegated GSDM as coordinator of the "Support for the dissemination of agroecological techniques in Madagascar" project (AFD/Malagasy government funding).



From CIRAD



FEATURES OF THE AREA

Annual rainfall: under the influence of the cyclonic regime, with highly variable rainfall, ranging from heavy (Southeast, 2 500 mm) to light (Southwest, 300-800 mm, 7-9 months of the dry season) from the Highland plateaus (1 300-1 500 mm) to the Midwest (1 000-1 500 mm, 6-7 months of the dry season)

Soils: poor quality soils (acidic, especially low phosphate level) to rich soils (volcanic soils)

Topography: Alaoatra Lake (*Tanety* hills, 800 m often rugged, and plains), Highland plateaus (plateaus and steep sloped hills, 1 300-1 800 m), Southeast (wolds, 0-200 m and steep sloped hills), Southwest (long glacis, 0-600 m), Midwest (plateaus and hills, 700-1 000 m)

Natural vegetation: humid and dry tropical forests (Southeast and Southwest), grassy vegetation elsewhere (*Aristida*)

Population: 18 million people, with high population densities on rich soils (Highland plateaus 60-200 inhab./km²) and low densities on degraded soils (10-60 inhab./km², sometimes 1-2 inhab./km², outside of the study area)

Economy: small-scale family farming (0.1-2 ha, manual cultivation, draught, sometimes mechanized)

Main crops: rice (rain-fed on hills, irrigated in lowlands and plains, on burnt forest clearings), food crops (cassava, Bambara groundnut, sweet potato, potato, bean, soybean, maize, vegetables, etc.) and export crops (coffee, vanilla, cloves, etc.)

Livestock herding: extensive cattle farming, goats (south)

Main constraints: relatively inaccessible and very expensive inputs, low rice yields, enclosed cropping areas, roads often impassable during the rainy season, economic stagnation, population boom, rural poverty, degradation of limited and fragile natural resources, infrastructure degradation, poor soils highly susceptible to erosion, disappearance of plant cover (bush fires, deforestation), harsh climate with cyclonic rain storms, rugged landscape

Partners: AFD/MAEE/FFEM/CIRAD/Malagasy Ministry of Agriculture/Twelve organisations belonging to the group GSDM (Direct seeding group of Madagascar): TAFE (*Tany sy Fampandrosoana*), ANAE (*Agence Nationale d'Action Environnementale*), FOFIFA (National Center for Research Applied to Rural Development), FIFAMANOR (*Fiompiana Fambolena Malagasy Norveziana*), FAFIALA (*Centre d'expérimentation et de diffusion pour la gestion paysanne des tanety*), BRL Madagascar, Bas Rhône Languedoc, SD Mad (*Semis Direct Madagascar*), INTER AIDE, AVSF (Agronomists and Veterinarians without Borders), VERAMA (*Les Vergers d'Anacardes de Masiloaka*), GRET (*Groupe de Recherche et d'Échanges Technologiques*), CARE International, Madagascar.

The aims of this project are:

- **to organise disseminators of these techniques** in a structured network oriented towards farmer training and the use of these new tools;
- **to organize farmers** so as to promote a new approach to farmland use;
- **to improve agricultural production and productivity** and thus fight rural poverty;
- **to control deforestation**, erosion and soil fertility degradation.

RESEARCH ON FARMS AND TO BENEFIT FARMERS

DMC development is an ongoing participative process involving collaborations with the main users, i.e. farmers. This process is implemented in the field at two levels:

- **Experimental units**, or reference sites, managed by researchers to design and develop DMCs: tests on cover plants, associations, breeding, adaptation, etc. The cropping systems are assessed at different input levels and organised along toposequences that are representative of different agroecological environments. Traditional cropping systems (with tillage) and DMCs are compared through these units.
- **Village land**, where volunteer farmers implement several DMC systems and adapt them or not. DMCs are thus implemented by farmers, with exchanges between researchers, technicians and farmers, which enables their evaluation, improvement and gives rise to complementary topics for research. In addition to this DMC development, cropping-herding integration, village land management and development, consideration of socioeconomic factors (integration on farms and throughout the local area), etc., are also dealt with on this scale. Farmer/scientist exchanges are thus crucial.

The sites are chosen to represent the diversity of agricultural conditions in the region. TAFAs have gradually built up and managed a large network of DMC reference sites that are currently installed in the main ecoregions of the island.

A VERY BROAD RANGE OF DMCs DEVELOPED FOR SMALL-SCALE FARMING

Madagascar is now clearly the most advanced country with respect to diversified technological DMC options for small-scale family farming. DMCs developed through research in this country are highly varied because of the high agroecological diversity in Madagascar. Technical references are available for the different ecoregions representative of the main types of soil, crops, socioeconomic situations and intensification levels that prevail: Highland plateaus, Southeast, Southwest, Aloatra Lake and the Midwest. These systems offer alternatives to traditional cropping systems, which are tailored to the demand and to very low-resource family farms, with:

- **a substantial crop diversification potential**, around a 'core' crop;
- **different intensification levels** (costs, initial investment, fertilisation, pesticides, etc.);
- **adaptable work intensity and laborious work**;
- **different technical skill levels**;
- **integration potential for cropping/herding** (forage production) and associations with trees.

The proposed systems can be adapted to the biophysical conditions on farms, to their economic situation (investment capacity, labour potential, etc.), to farmers' objectives and social environment. Even the poorest farmers can implement DMCs using no-input crop management sequences. A range of seeders that were initially designed in Brazil have been tested: motorised seeders for large plantations, animal-drawn seeders, seeding wheels, manual cane planters, etc. The poorest farmers can simply use a stick or *angady* (local hoe). Cover plant species (also forage species) have been identified for each agroecological area and are now being multiplied. Main crop varieties have been selected and tested in DMC systems. ■



SYSTEMS ADAPTED TO THE RANGE OF CONDITIONS IN MADAGASCAR



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Malagasy DMCs fulfil the priorities of farmers, who are often poor—providing attractive income, with low to nil inputs, while ensuring agricultural sustainability. The systems are also designed to meet the agroecological specificities of each region. Depending on the setting, this can include:

- Crop associations (cereals + legumes), with both crops generating biomass, recycling nutrients, while the legume crop provides a source of nitrogen.
- Crop sequences (legumes/cereals; cereals/legumes) that ensure **nutrient recycling**, with soil restructuring by the second crop, biomass production by all crops and nitrogen input via the legume crop.
- Associations of crops and cover plants, with biomass- and nitrogen-producing legumes (*Stylosanthes guianensis*, etc.) or perennial forage grasses (*Brachiaria ruziziensis*, etc.).
- Sequences of crops and cover plants (hills and lowlands) for nutrient recycling and restructuring of the soil profile by cover plants, biomass production by the two plants and nitrogen input via the legume crops.

(From Balarabe, 2004; Séguy, 2005)



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3.3 DMC in Madagascar

b. Main impacts

DMCs overcome the main constraints of traditional cropping systems—labour needs, production costs, **weed** control, better water management, etc.

ALTERNATIVES TO TAVY (SLASH-AND-BURN FARMING)

Tavy is a major cause of deforestation and soil degradation. Conversely, clearing without burning keeps soils from being carried away and preserves or even improves their fertility. After clearing, the biomass is left in the field and cover plants are sown directly in this mulch (e.g. *Mucuna*), thus providing soil cover and a source of nitrogen, while the weeds are controlled and the natural organic matter decomposition processes left to continue functioning. In the second year, rain-fed rice can be sown directly in the *Mucuna* cover, so the soils are not subjected to erosion. A phosphorus application (or controlled soil burning) is recommended on depleted soils in order to generate interesting yields in the first year, which can be maintained in subsequent years through minimum input applications, thus avoiding the need to clear new plots. Crop yields are thus stabilised and even increased over time. This cropping system reduces deforestation by encouraging farmers to continue cropping on the same cleared plots.

CROPPING ON IDLE LAND

Vast areas are abandoned by farmers because the soils are too infertile to profitably grow crops using traditional techniques. DMCs offer solutions to enhance the fertility of these extremely degraded soils:

- **The controlled soil burning technique** enables farmers to grow rice, even without fertilizers, on idle *Tanety* soils (hill slopes).
- **The use of cover plants** that can grow in very infertile soils can quickly restructure and enrich these soils (1-2 years), while providing excellent fodder (*Brachiaria* sp., *Stylosanthes guianensis*, etc., with pure crops or in associations with food crops). Although fertiliser inputs would be warranted on the most degraded soils, these techniques generally enable the development of areas with very little chemical fertiliser input. After 1-2 years, *S. guianensis* can be grown as cover under direct seeding no-input (fertilisers or herbicides) conditions and thus enable farmers to obtain rain-fed rice yields of up to 5 t/ha in areas where soils were previously highly degraded.

Implementation of DMC techniques can control or even eliminate the main **weeds**, e.g. *Imperata cylindrica* (controlled by *Mucuna* or *Brachiaria humidicola*), *Cyperus rotundus* (controlled by sorghum mulch) or *Striga asiatica* (combined effects of soil cover, shade, temperature regulation, higher organic matter production, etc.).

Weeds can even be used as cover for DMC—bean, soybean and even rice (with nitrogen input) yield very well when direct seeded on Bermuda grass (*Cynodon dactylon*) that has been knocked down with one herbicide spray! Areas abandoned by farmers in the midwestern region due to its colonization by *Striga* have thus been able to cultivate the land again using these techniques.



SOIL BURNING, AN INEXPENSIVE TECHNIQUE TO ENHANCE PRODUCTION AND RESTORE SOIL FERTILITY



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Soil burning (or 'smouldering') involves burning dried grass covered with 10 cm of soil in a 20 cm deep ditch with aeration every metre. When associated with DMC,

this practice generates spectacular soil fertility and crop yield results in different types of soil (soybean/rice rotations) in the Malagasy highlands:

- **The chemical properties of the soil**, which was initially poor, are improved.
- **Rain-fed rice production** is equivalent to that obtained with high chemical fertiliser input (1 t/ha yield gain in rich volcanic soils, and 3 t/ha in poor ferrallitic soils).

The frequency of this practice should be limited in soils with low organic matter content so as to avoid its partial destruction. Malagasy farmers have adopted the soil burning technique in several regions (Alaotra Lake, Highlands).

(from Michellon *et al.*, 2005)

RICE FIELDS WITH POOR IRRIGATION MANAGEMENT —CROPPING VERSATILE RICE VARIETIES

Rice is grown traditionally under poor irrigation management conditions over a very large area (over 70 000 ha, just for Alaotra Lake). Yields are highly irregular and low (1 t/ha) due to rainfall delays (thus delaying transplanting and decreasing yields). The solution is to adopt versatile rice varieties (SEBOTA bred by Séguy *et al.* in Brazil). These varieties can be grown under all types of water regimes, from strict rain-fed (when there is sufficient rainfall) to irrigated!

It is thus possible to sow the crop under rain-fed conditions, while awaiting rainfall, and then continue with irrigation when the rainwater supply is finally available. These varieties reduce the impact of climatic variations, while boosting production (3 t/ha without fertilisers, 6 t/ha with fertilisers) and thus to intensify cropping at low risk.

Rice production could thus be increased by as much as 100 000 t/ year just at Alaotra Lake! Legumes can be cropped during the dry season to potentially enhance farmers' income and food supply, while inputting nitrogen in the soil and providing mulch for an early direct seeded rice crop the next year.

ENHANCEMENT OF FOOD SECURITY IN SEMI-ARID AREAS

DMCs improve the water balance very considerably by reducing runoff and evaporation via the plant cover and increasing infiltration and **soil porosity** and deep rooting of the crop cover. It is thus possible to obtain high stable production in semi-arid areas (Southwest), even in dry years (less than 300 mm rainfall in 2003-2004) and on sandy soils, as the plants tap water from deep soil horizons accumulated during rainy years. In areas with high wind erosion (*Androy*), where large areas are threatened, DMC substantially help to reduce the loss of clay particles due to wind, thus encouraging farmers to not abandon their land.

ECONOMIC PERFORMANCES FROM THE FARMER'S STANDPOINT

From an economic standpoint, DMCs increase farmers' income and soil 'capital'. Some farmers have been able to boost yields by 2- to 3-fold when they efficiently use DMC techniques! These systems enable farmers to increase the number of crop cycles and the area used for rain-fed crops. Sowing can be done after the onset of the first substantial rains, so the produce can then be marketed during a period when market prices are very high (bridging the March-April food gap). Labour time and laborious work are also reduced, especially at critical sowing and weeding times.

CROP DIVERSIFICATION—FORAGE PRODUCTION AND INTEGRATION WITH LIVESTOCK PRODUCTION

Most cover plants used in DMC provide excellent forage, thus facilitating their integration with livestock production systems. This integration is often essential for the development of DMC techniques while also enhancing natural resource conservation (burning is no longer required, herders have access to abundant high quality forage throughout the season). Cover plants, regardless of whether they are in associations, sequences (production during the dry or rainy season) or rotations with the main crop, can markedly increase biomass production and the forage supply. For instance, an association between cassava (*Manihot esculenta*) and *Brachiaria* (*B. ruziziensis* or *humidicola*) is efficient, i.e. 3-5-fold increase in cassava yields, high top-quality forage production and improvement of the soil structure for subsequent crops. Trees also benefit from the restructuring and protection of soils by these cover/forage plants.

LARGE-SCALE DISSEMINATION—THE 'AGRARIAN REGION' APPROACH

There has been a spectacular increase in DMC cropping areas, in farmers' demand, in the number of concerned farmers' groups and associations formed in some ecoregions (Alaotra Lake and the East coast). During the 2005/2006 season, the total DMC cropping area was 2 900 ha, for around 4 600 farmers. TAFE and CIRAD have developed

an agrarian region oriented approach for large-scale dissemination of agroecological techniques. It is based on technical control of a broad range of systems and a simple understanding of farm functioning patterns. Proposals can thus be better tailored to meet farmers' needs, while offering effective farm management advice. Interventions are carried out on a small catchment basin scale, thus integrating different landscape units, stakeholders and their interactions. This approach aims to:

- **Train farmers** so that they can appropriate these techniques and the agricultural mechanisms involved (for 2-3 years).
- **Organise farmers in associations** (or support already existing organisations) so as to determine the socioeconomic factors that hamper wide dissemination (common use of spraying equipment, easy access to rural credit, etc.).

In addition to its dissemination function, this 'agrarian region' approach enables:

- **To implement DMC in the field**, and integrate them on a much broader scale.
- **To get farmers' opinions** on these systems that can be taken into consideration in research projects.
- **To train different users** (technicians, farmers, etc.).
- **To identify and promote motivated farmers** who have assimilated these practices so that they can become 'leaders' in DMC dissemination to other village communities.
- **To draw up guidelines on a large farming region scale**, for integrated management of agrarian regions in Madagascar.

These cropping systems are disseminated in a suitable farming environment: safeguarding land, cover plant, input and small equipment supply, credit access for Malagasy farmers with low investment capacities, formation of associations (common use of equipment, between farmer exchanges, etc.), etc.

ESSENTIAL TRAINING OF DMC USERS

GSDM's strategy for the dissemination of DMC techniques is based on a simple principle, i.e. let farmers choose their systems and intensification levels on the basis of accurate information on the potential, constraints and risks of these systems. This requires close individualised advice, so it is essential to train extension staff. Some of these systems, i.e. the simplest and most robust, could be recommended for quick dissemination in specific situations: systems proposed for rice fields with poor irrigation management, etc. However, DMC dissemination is usually complex and requires a long apprenticeship and special know-how.

Training of different stakeholders is required for the dissemination of a set of practices, methods, systems and solutions—not just a technical package. Long training through field practices has been set up. An agent should thus obtain a year of training (to cover all agricultural activities) as an apprenticeship on DMC use, but also on the specific approach to DMC dissemination on an agrarian region scale. This training takes place in model cropping areas set up by TAFE for pre-dissemination of DMCs. Madagascar is currently a privileged DMC training area for the African continent and much further beyond (especially Southeast Asia). ■

3.4 Cereal based DMCs in northern Tunisia

a. Developing cereal based DMCs on dead plant cover

➤➤➤ How can DMCs be set up in a Mediterranean area in a mechanized farming setting?

INTRODUCTION OF DIRECT SEEDING IN TUNISIAN CONDITIONS

Tunisian agriculture (mainly cereals and sheep herding) is highly mechanized but yields are quite low. Despite fertilizer applications, cereal yields have changed very little since ancient times! Major problems have long hampered this agriculture (shortage of water, severe rainfall, etc.) and resulted in soil erosion and degradation. These phenomena worsened during the 20th century with population growth and land pressure. **Conventional** cropping practices trigger erosion and aggravate these processes (disc ploughing down slopes, bare soils, reduced fallows). Water and soil conservation (WSC) techniques, which are costly for the government, have been implemented to solve these problems but are generally not adopted by farmers.

Tunisian agriculture is subsidised, i.e. guaranteed prices (cereals and milk), investment and production credits, and modernisation investment subsidies. This situation enables a few large-scale farmers to invest in specialised seeders required for direct seeding. The Tunisian administration is, however, limited with respect to the development and dissemination of agricultural innovations. In the Tunisian setting, large-scale farmers (cropping at least 100 ha) are the key driving force behind innovations such as direct seeding.

PROJECT IN NORTHERN TUNISIA TO PROMOTE SUSTAINABLE AGRICULTURE

Direct seeding was first introduced in 1999. The aims were to demonstrate that rain-fed cropping of cereals (durum wheat, barley, oats) could be sustainable, productive, while integrating livestock production under semi-arid Mediterranean conditions. AFD and CIRAD first introduced the direct seeding concept in three successive phases:

- **Initiation during the 1999-2000 season (Siliana and Kef)** following the AFD initiative to boost the awareness of the Tunisian Ministry of Agriculture and Water Resources.
- **A 4-year experimental programme (2000-2004)**, within the framework of two Tunisian integrated rural development projects (PDARI projects at Siliana and Kef, co-funded by AFD). The project was extended to the Bizerte, Béja and Jendouba governorates in 2002.
- **A specific complementary project (2002-2006, FFEM funding).**

These projects are set up in northern Tunisia, where the soils are high quality and where CTC and an agriculture school (ESAK) are located, which could provide efficient dissemination support (modification of direct seeding techniques, training). CIRAD provides technical and scientific support. The private sector is also highly involved in importing specialised seeders (mainly from Brazil) to equip farmers for direct seeding.



From CIRAD



FEATURES OF THE AREA

Annual rainfall: low (350-800 mm/year)
Soils: deep 'young' soils (brown calcareous vertisols), shallow soils, 'ancient' soils (brown fersiallitic or isohumic soils)
Topography: broad plains, hills and mountains (up to 1 000 m elevation)
Natural vegetation: dry forest and Mediterranean brush
Population: 10 million people (50-200 inhabitants/km²)
Economy: small mixed cropping-herding farms to large-scale cereal farms (50-200 ha, mechanized farming), livestock production
Main crops: rain-fed and irrigated cropping, mainly cereals (durum wheat, barley, soft wheat, oats, sorghum maize, etc.), and to a lesser extent legumes (horse beans, chickpeas, lentils, peas, alfalfa, etc.), trees and oil crops
Livestock herding: extensive (sheep and to a lesser extent cattle) grazing of straw by wandering herds

Main constraints: very low water table, irregularity and severity of rainfall, steep slopes, shallow soils, soil erosion and degradation, high pressure on land, excessive parcelling of land on slopes, cropping of fragile land, inappropriate conventional cropping techniques, problems of credit access and cropping methods too expensive for most people, administration limited for the creation and dissemination of agricultural innovations

Partners: AFD/FFEM/CIRAD/Ministry of Agriculture and Water Resources of Tunisia/CTC (Technical Centre of Cereals)/ESAK (Higher School of Agriculture of Kef)/SCEA QUILLET (*Société civile d'exploitation agricole Quillet*)/LAMS (*Laboratoire d'analyses et de microbiologie des sols*)

SETTING UP FIELD TESTS—‘ON FARMS, FOR AND WITH FARMERS’

The Tunisian approach, developed with the support of CIRAD, is an action research initiative ‘On farms, for and with farmers’^{4.1} with the emergence of ‘leader’ farmer-researchers. The first direct seeding trials were conducted on a few farms. CTC then set up **conventional** cropping plots close to farmers’ direct seeded plots to facilitate comparisons between these two cropping systems. Other farmers then planted plots via direct seeding, and the same between system comparisons were made. The Tunisian administration initially funded the material costs (seeders, herbicides, etc.). A specialised Brazilian seeder was selected. These techniques have been highly successful, so a direct seeding association has been gradually formed with the first farmer-researchers who are now equipped with seeders.

DIRECT SEEDING AND DMC CROPPING SYSTEMS TESTED

The cropping systems tested in northern Tunisia are based on conventional crop rotations (cereal/cereal/fallows; cereal/cereal/forage or legume):

- **On dead plant cover (SCV, almost without cover plants)**, with some crop residue that is traditionally grazed by sheep herds during the dry season (herding component in Tunisia is essential and should be preserved).
- **With rotations** integrating cereals and legumes still not streamlined (many cereal/cereal rotations).

So far, DMC practices have been implemented almost without cover plants (crop residue provides cover). However, cover plant species are currently being tested under controlled conditions (CTC, ESAK): *Cenchrus*, *Cynodon*, *Brachiaria*, panic grass (*Echinochloa*), kikuyu grass, finger millet, sorghum, millet, *Cajanus*, *Stylosanthes*, alfalfa, *Medicago*, *Lupinus*, clover, berseem clover, cockshead, fenugreek, raygrass, oats, vetch, etc. A few farmers are also testing plant covers on their farms (oats in late summer or autumn, sorghum in spring). However, few diversified DMC scenarios have been assessed to date, even though the diversification process is already under way on farms run by these progressive farmers. ■



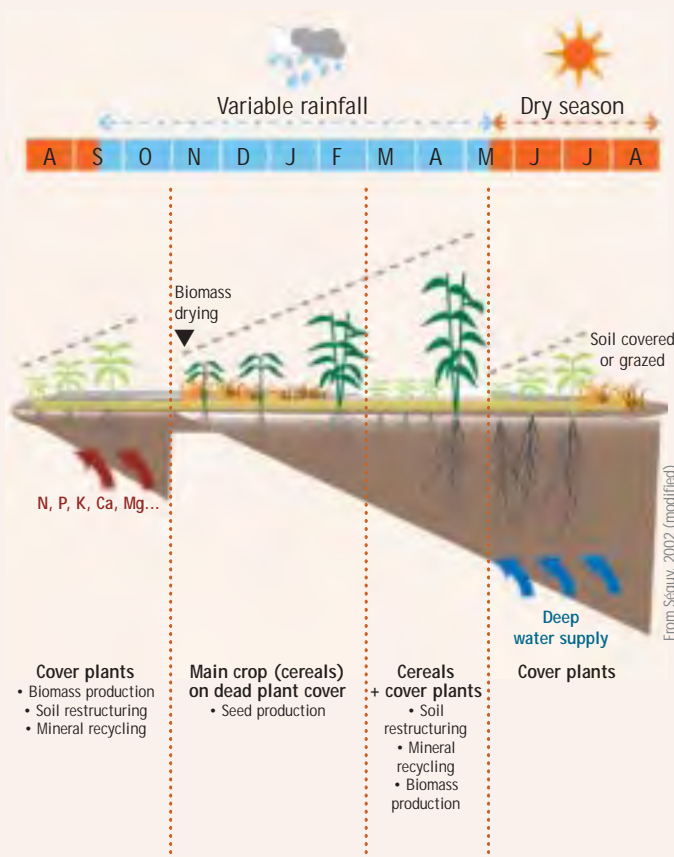
DMC IN NORTHERN TUNISIA WITH CEREALS GROWN ON DEAD PLANT COVER



© J.-F. Richard

Different DMCs have been proposed to enhance both cereal and biomass production. Cover plants must be adapted to the low variable rainfall

conditions of Tunisia. Biomass is produced the same year as the main crop (cereals).



Sheep grazing on durum wheat crop residue (Mateur, Tunisia)

© J.-F. Richard

3.4 Cereal based DMCs in northern Tunisia

b. Les principaux impacts

The experiments carried out since 1999 on direct seeding have generated significant results: stabilised or even slightly better cereal yields, especially during drought periods, reduced mechanization costs, better water management, etc. However, these results still have to be firmly validated.

BETTER SOIL PROTECTION AGAINST EROSION

Soil loss due to erosion can be reduced by 20-30% on average (2-4 t/ha/year under direct seeding vs 3-7 t/ha/year under **conventional** farming, based on a very small number of observations) over the first 3 years of cropping with direct seeding (little residue covering the soil). Soil loss is more reduced when there is greater cover. The most fertile surface soil layer is thus protected. The soil organic matter content increases (+0.3% after 3 years of direct seeding), therefore enhancing the fertility and productivity of agricultural soils.

Indirectly, dams are slower to fill and damage to other public infrastructures (roads, buildings, etc.) is limited when direct seeding is applied on a catchment basin scale. This indicates that the costly work of CES is not as crucial or even warranted on cropland with less than 10% slope.

BETTER WATER SAVINGS

This water savings is important for a country in which water is a limiting factor. It is achieved through a decrease in runoff and an increase in water infiltration in soils cropped using direct seeding (65 mm/h vs 45 mm/h under conventional systems). Moreover, water evaporation is lower in soils under direct seeding (5% reduction) and thus the moisture level is up to 20% higher in these soils! Irrigated crops thus require less water, which in turn is more available for rain-fed crops.

HIGHER SOIL BIODIVERSITY

Direct seeding stimulates soilborne microfauna (mites, collembola, etc.) and mesofauna (40-60% more arthropod species, depending on the site) populations. The number of individuals per coleopteran and ant species also increases considerably. Note that soil fauna increases its **porosity**, thus facilitating crop root development, etc. Durum wheat main roots were found to be 5-10% longer in direct seeded crop fields, thus increasing production, especially under extremely arid conditions.

POSITIVE ECONOMIC IMPACTS

Both farmers and communities benefit economically from direct seeding—farm incomes are increased while production is stabilised. Moreover, less public funds are used (saving expenses associated with costly WSC techniques).

Direct seeding has the following positive economic benefits for farmers:

- **Lower mechanized labour time** and a reduction in peak work loads, better soil support under moving machinery. This latter point is essential for sowing just after the first rains, which can broaden the working period range (spraying and fertiliser applications).
- **Better agricultural results** as compared to **conventional agriculture** through better compliance with optimal working times, even though the soil cover is still minimal, with slightly higher yields. Direct seeding was found to be more suitable for barley than for durum wheat crops. Seed quality (specific weight) is significantly improved.
- **Mechanization costs are lower** with direct seeding for most crops (7-20% depending on the crop). However, pesticide costs offset this gain (techniques are currently being adjusted) and bring the per-hectare costs to within the range of those incurred under conventional agriculture conditions.
- **Reduced fuel consumption**, estimated at around 50-80 l/ha.

Expenses associated with direct seeding are high at first, i.e. acquisition of seeds, herbicides, specialised seeders and, in some cases, a high-power tractor. However, after 3 years of testing, the gross margins (sales figures less the production costs) were found to increase by 50% for barley, 58% for soft wheat, and 10% for durum wheat as compared to conventional agriculture.

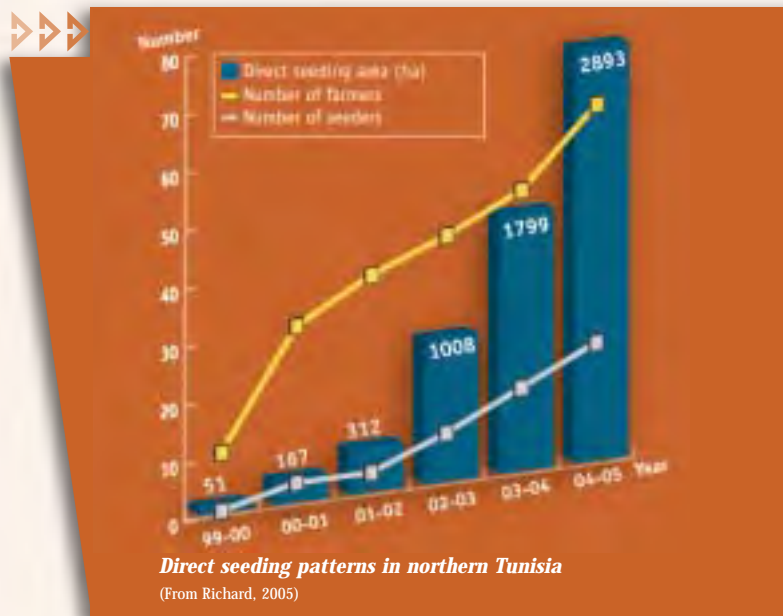


Comparison between conventional agriculture and direct seeding (Kef region) for durum wheat production in 2003

(From M'Hedhbi *et al.*, 2004)

For the community, some economic benefits associated with the adoption of direct seeding were measured and others are expected:

- **In the long term**, investment cost savings (estimated at 400-600 DT/ha) for mechanical anti-erosion berms (WSC) in crop fields are expected.
- **Direct seeding use** has several effects on carbon: elimination of the release of carbon that is usually produced by tillage and erosion, reduction in emissions associated with fuel consumption and carbon storage via an increase in soil organic matter. It is calculated that with 1 ton of carbon at US\$10 (within the framework of the market for carbon emissions established under the Kyoto Protocol) and storage of 14 t/ha over 10 years, a 200 ha farm would have a potential cumulated gain of US\$28 000, i.e. the cost of a specialised seeder!
- **The quantity of stubble available for livestock grazing** would be much higher (increased straw production), thus enabling an increase in herd size as compared to traditional systems with tillage. This would begin right after the June harvest and last throughout the driest period, thus gradually reducing the stubble area (main feed for sheep during this critical period).
- **Other impacts** could be mentioned but the economic gains are harder to assess: replenished water table, reduced silting of dams, etc.



➤➤➤ **Tunisian farmers' opinions on direct seeding (in descending order of importance)**
(From Richard, 2005)

Advantages

- Reduction in farm expenditures and production costs
- Improved crop yields
- Erosion control
- Enhanced water savings
- Higher fertility

Drawbacks

- Challenging long-standing practices such as tillage
- Cultural change: considering that new cropping systems are possible

More time is required to be able to assess the long-term impacts of direct seeding and the slow changes (such as the increase in soil organic matter) and also to switch from direct seeding to a real DMC cropping system. ■

➤➤➤ THE SEEDER—ESSENTIAL FOR THE ADOPTION OF DIRECT SEEDING IN TUNISIA



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In mechanized agriculture, it is essential to purchase a specialised seeder so as to be able to properly implement this technique.

In Tunisia, where mechanized cereal cropping prevails, a Brazilian seeder (SEMEATO) was selected for its technical features. The seeder has to be able to penetrate compact (untilled) soils—it is heavy (weighing threefold more than a conventional seeder) and has discs to be able to penetrate compact soils without clogging. It also requires a more powerful tractor (at least 90 cv) than most found in Tunisia. In addition, it is threefold more expensive than conventional seeders. The features of this specialised seeder and its cost explain why only large-scale Tunisian farmers have so far been able to risk investing in the equipment needed for direct seeding.

From J.-F. Richard (pers. comm.)

➤➤➤ COMPARISON OF GAINS AND COSTS ON TWO REFERENCE FARMS IN NORTHERN AND SOUTHERN TUNISIA

Conventional cropping techniques and direct seeding were compared for a farm in the north (rainfall 500-700 mm/year) and another in the south (300-500 mm/year), both based on cereal and legume production:

- In the north, durum wheat production costs were 311 DT/ha under DMC and 353 DT/ha under conventional farming, i.e. a gain of 12%.
- In the south, durum wheat production costs were 299 DT/ha under DMC and 309 DT/ha under conventional farming, i.e. a gain of 3%.
- In the south, DMC generated a gain of 3% for pea crops.

(From Chouen *et al.*, 2004)

INCREASED NUMBER OF FARMERS USING DIRECT SEEDING

Farmers are increasingly interested in direct seeding, but these are mainly large-scale farmers because considerable investment is required to purchase a specialised seeder, which in turn must be pulled by a relatively powerful tractor. So far, farmers who have adopted direct seeding are relatively young (mean age of head farmers: 54 years old), with farms of 500 ha on average, which are well equipped and located on plains and piedmonts. Direct seeding adoption is promoted via on-farm demonstrations, and through the drive and vitality of the most experienced farmers and specialised seeder salesmen. The recorded agro-economic profits and feasibility of the techniques are also, of course, key features in favour of the adoption and dissemination of direct seeding. Cropping areas under direct seeding are rapidly increasing (51 ha in 1999 vs 2 900 in 2005). These areas currently concern direct seeding plots, i.e. so far not many specifically implement DMCs.

4 DMC training, dissemination and adoption



e. K. Naudin

Focus 4 covers various aspects of DMC dissemination and adoption. CIRAD's action research on DMCs is aimed at creating and disseminating highly diversified cropping systems to benefit smallholders, who are often poor, without access to inputs and whose land is seriously eroded and degraded. The main challenge is to promote this new and truly sustainable agricultural strategy so that it can be widely adopted in intertropical regions. This involves information dissemination, training of different stakeholders and adoption of this new agricultural technique by farmers—the end users. DMC dissemination and adoption does, however, come with some constraints and risks since this “new agricultural strategy” requires major changes in crop management sequences, farm and land development and management.

CONTENTS

4.1 DMC: from research to dissemination

An overview of the main action research principles at CIRAD and factors essential for efficient DMC dissemination

4.2 DMC adoption by farmers

DMC benefits and constraints for successful adoption by farmers

FOR FURTHER INFORMATION (SELECTED REFERENCES)

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- **Most of these documents can be downloaded** from CIRAD's Agroecology website: <http://agroecologie.cirad.fr/index.php?rubrique=librairie&langue=en>
- **Documents that have been published in *La gazette des SCV au Cirad*** can be obtained upon request from Michel Raunet (CIRAD), michel.raunet@cirad.fr



*DMC training,
dissemination and adoption*

4.1 DMC: from research to dissemination



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➤➤➤ A major challenge addressed by action research...

In conservation agriculture, DMCs provide a broad range of technical on-farm solutions for farmers, and with their participation, thus enabling them to adapt to specific local constraints. Using these unconventional techniques requires considerable know-how, often contrary to traditional farming practices. The introduction of any new agricultural innovations necessitates in-depth discussions with farmers, technical proficiency, and specific training so that they can be tailored to specific local conditions. Farmers who adopt DMCs should benefit from individual supervision, and then be advised over a relatively long period to enable them to more easily deal with this major change in their farming habits.

ON-FARM DEVELOPMENT OF DMCs FOR AND IN COLLABORATION WITH FARMERS: ACTION RESEARCH



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Farmers are involved in action research at all stages of DMC development. This is a progressive and participatory initiative “for and with farmers on their farms” developed by CIRAD (L. Séguy). It is implemented in the field at different levels:

- **In controlled environments** (reference sites accessible to farmers who participate in development activities) managed by scientists to design and develop DMCs—assessment of the agricultural, technical and economic performance (first approach) of different innovative DMCs, their impacts (biological quality of soils, water and crops), compared to traditional reference systems, etc. The plots are organised along toposesquences that are representative of different agroecological environments. These also serve as “DMC showcase” sites where farmers can gain technical and practical experience on managing these cropping systems.
- **In the field** (reference farms) where volunteer farmers implement several DMC systems of their choice, on a real scale, while tailoring them, when necessary, to meet their own objectives. DMCs can be assessed and improved on the basis of results obtained by farmers and their discussions with scientists. They also contribute to the adoption and in situ training of farmers (field demonstrations with presentations of comparative agricultural, technical and economic results).
- **On a larger scale** (cropland around villages), implementing DMCs on this level is useful to check their performance relative to **conventional systems** (agricultural, technical and economic criteria), to assess the impacts on the environment and on agricultural systems, and to determine the potential regional economic benefits. Other factors can also be tested on this scale, e.g. integration of crop and livestock farming, land management and development, etc.



APPLIED RESEARCH IN TUNE WITH THE FIELD SITUATION



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“DMCs are designed and adjusted in developing countries in a participatory action research framework. Farmers and other development stakeholders

are involved, starting off with their current system and limitations, then alternative cropping systems are practically modelled, which are in turn developed in the field. [...] Scientific research, which should primarily be applicable, is thus connected with current field situations, while designing tailored systems that could be adopted by farmers in the future (preventive and precautionary agriculture). This in situ so-called “creation-dissemination-training” research is backed by experimental units that are managed by scientists and farmers on reference farms in which voluntary charismatic and influential farmers implement systems that they have chosen in the experimental units as-is or have modified to meet their needs. Together the reference farms are representative of the regional diversity (physical and socioeconomic settings). On the experimental farms, cropping systems are organised in a matrix pattern on representative toposesquences. Beginning with traditional cropping systems, the new systems are developed by gradually incorporating, in an organised and controlled manner, more efficient production factors. [...] These matrices and reference farms are sites of activity, development, innovation and training. They also represent a valuable monitoring laboratory for scientists and a breeding ground for diversified cropping systems.”

(from Séguy and Chabanne, 2005)

Selected sites should be representative of the diverse range of possible farming situations (physical and socioeconomic settings) so as to make it easier to draw up technical and economic guidelines on a broad range of systems. In this way, farmers can obtain personalised advice. Action research thus generates a multidisciplinary discussion and farmers serve as key players in development.

DMC: A NEW PARADIGM?



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Major changes in crop management sequences (plots) and in farm and land organisation and management are necessary to facilitate DMC adoption by farmers. DMCs are not simply technical packages to be disseminated. They are a set of practices, methods, systems, etc., that are implemented

gradually—such profound changes cannot be made from one day to the next! Farmers must first acquire new knowledge and expertise (on cover plants, etc.). Then they have to make a broad range of decisions concerning DMCs, e.g. the right technical options, cover plants, etc. Finally, despite the substantial initial economic risks and impacts involved (time required to shift from traditional cropping systems to SCVs), DMCs will ultimately enhance smallholders' productivity. Social aspects are also crucial, especially in farming communities in developing countries—decisions on such profound changes cannot be made individually, the social group as a whole has to validate these major innovations!

Cultural, social and/or technical barriers may hamper the change process. The DMC concept actually differs somewhat from **conventional agriculture** principles, especially with respect to tillage and having “clean” fields, etc. The adoption process thus requires a major change in farmers' mentality, as well as that of other associative, political, institutional stakeholders, etc. This is inevitably a long slow process, sometimes taking an entire generation. The development and dissemination of these techniques should be planned over the long term, considering the difficulties involved in transferring information and in changing traditional models. Technical, social, cultural and even political problems have to be identified, understood and overcome to facilitate DMC development and dissemination.

ESSENTIAL TRAINING FOR THE DIFFERENT STAKEHOLDERS

DMC adoption often questions farmers' traditional cropping practices. Training is therefore essential. During the first training phases, farmers must be closely supervised by technicians who have practical training and are fully experienced in setting up DMC systems on the basis of farmers' conventional systems. Extension agents are trained to provide them with skills in both implementing and disseminating agroecological techniques. The trainee must gain knowledge on DMCs, but especially practical know-how in the field and in dissemination operations.

Training should be an ongoing process, specifically targeting all stakeholders, including farmers, policymakers, farmers' organizations, technicians, educational staff, students, etc., and carried out under real field conditions (controlled and natural environment) throughout the creation-dissemination process. This training is supported by all action research initiatives under way.



DMC TRAINING IS AVAILABLE...

Diploma-oriented training: Master's degree courses on “no-till agriculture” in Brazil (University of Ponta Grossa – UEPG, CIRAD/UEPG convention). There are also training modules designed to meet the needs of different research and development stakeholders, e.g. farmers, technicians, engineers, students, etc., in countries that have the most experience on DMC implementation (Brazil, Madagascar, Laos, etc.).

PRIVATE SECTOR INVOLVEMENT IN DMC DISSEMINATION

Successful DMC dissemination depends closely on the availability of suitable equipment. The private sector should thus supply tools adapted to DMC practices. Farm machinery manufacturers must work with farmers to adapt and ensure access to machinery, for both large-scale modern mechanised farms (e.g. Tunisia) and family smallholdings in poor developing countries (Brazil, Madagascar, Laos, etc.). Moreover, these manufacturers could have a marked impact on the dissemination and adoption of these new cropping practices since they are in regular contact with farmers.

KEY ROLE OF FARMERS' ASSOCIATIONS



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The professional agricultural community, especially farmers' organisations, spearheads DMC development in their home countries. Brazilian experience shows that extension services and “leader” farmers, who are the first to realize the benefits

DMCs offer, are the forerunners of change in their regions. These farmers serve as local opinion makers. Their facilitation and demonstration activities convince other farmers on DMC performance and positive impacts. Indeed, DMCs have been able to develop successfully in some regions thanks to a few pioneer “visionaries”, who have a considerable influence in convincing other farmers. Progressive large-scale dissemination of DMCs can thus be effectively mediated by leader farmers, i.e. triggering a wavelike spreading phenomenon through their influence on interested farmers. They encourage these farmers via demonstration visits on their farms, and discuss their field results at conferences, etc. The formation of farmers' associations is very important.

In Brazil, beginning in the 1970s, farmers began gathering in communities, then associations, clubs, federated cooperatives and sometimes in research and development support foundations. These organisations now have a key role in DMC dissemination—seminars, meetings information exchanges, etc. They also publish magazines (*Cerrado direto* and *Plantio Direto* in Brazil, *The conservation farmer* in Australia, etc.). In addition, these associations can pinpoint socioeconomic factors that may hamper widespread dissemination (e.g. common use of equipment), while providing support for farmers at the beginning of the adoption process. They represent one of the keys to successful adoption, training, information exchange and innovation. In addition, networks facilitate exchanges between different countries or regions. Public awareness on DMC features is also promoted through the media (specialised journals, local newspapers and TV stations) in support of their widespread adoption. ■

4.2 DMC adoption by farmers



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▶▶▶ What are the key factors for successful DMC adoption by farmers?

DMCs offer many benefits for farmers—stable crop yields, lower production costs, labour savings, less laborious work, no soil erosion, etc. Farmers thus have many reasons to adopt DMCs. However, they have to adapt to these new systems and take certain risks, especially in the first years after their adoption. DMC adoption decisions are often made in a risky setting (unforeseen natural and market-related events). Farmers' behavioural responses to risks must therefore be taken into close consideration.

DMC ADOPTION CRITERIA—FARMERS' VIEWPOINT

Farmers usually point out that the substantial economic potential is a prime reason for adopting DMCs. The technical feasibility of DMCs and the short-term economic potential (reduction in production expenditures, profitability, stable crop yields, etc.) are essential for farmers. The environmental motives, such as erosion control, are not sufficient to prompt farmers to change their farming practices unless the situation has been aggravated by serious social and economic factors. Very high environmental pressure can then become a key motive for farmers to adopt DMCs. A few other decisive factors should also be mentioned, including the reduction of climate-related risks, enhanced water savings, better soil fertility in cropfields, longer field access periods, etc.

FACTORS THAT IMPEDE DMC ADOPTION

Many different factors may hamper DMC adoption by farmers, especially the technical, socioeconomic and political constraints and risks involved, e.g. farmers have to quickly become proficient in DMC techniques, market new products, acquire special farming equipment, etc. These overall factors may discourage farmers from taking the risk of adopting these new unknown techniques. It is thus crucial to improve the agricultural situation in order to set the stage for successful DMC dissemination/adoption. Some of these adoption constraints have been identified:

- **Mastering new techniques** (especially herbicide treatments).
- **The low investment capacity** of most farmers in developing countries, thus necessitating access to credit. Indeed, the required chemical products (herbicides), seeds (cover plants) and adapted tools (seeders, etc.) are expensive. Farmers claim that the lack of credit access is a major constraint to DMC adoption. The equipment cost is the main factor limiting DMC expansion in certain areas like Tunisia where only farmers managing large plantations are able to quickly adopt them. Smallholders certainly cannot take high economic risks!
- **The availability of inputs and farming equipment** is also an important adoption factor.
- **Competition with livestock herding** or other types of landuse is a considerable problem in semiarid regions, especially in Africa. Livestock grazing makes it hard for farmers to maintain plant cover in their fields. Preliminary agreements between land users around villages are essential, and traditional authorities should be highly involved in this process.



DOES LIVESTOCK REARING CURB DMC ADOPTION?



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Crop and livestock farming have long been considered as the two main pillars of rural development, but these two distinct activities are hard to integrate in many small-scale family

farming situations. Livestock grazing can be problematic when harvest residue left in the fields is not derived from forage crops and also when farmers are trying to maintain permanent plant cover in their fields. The plots should then not be grazed after the grain harvest, which is a major impediment for societies that traditionally graze their herds in common rangelands, as occurs in Africa ^{3.1}. African customary laws authorise farmers to graze their animals on any biomass left in the fields after the crops have been harvested (land is thus considered as common property). This paramount problem touches the foundations of heritage management in many African societies. It is common to hear, in areas where crop and livestock farming coexist, that DMC systems cannot be adopted due to competition between crops and livestock for biomass, especially in the dry season. Better integration of agriculture-livestock farming-natural areas should thus be sought to promote fodder use of crop residue while preserving plant cover. Local communities should draw up collective regulations to protect plant cover (from wandering herds, bush fires). Existing biomass should also be better managed, while boosting its production so that its use by DMCs will not be detrimental to livestock herding.

- **Land insecurity:** collective land management activities, such as those associated with DMCs, raise the problem of individual or collective land appropriation and thus the long-term use of managed lands. Land securement can benefit DMC dissemination. Farmers should obtain a guarantee that they can use the land for a long enough time to reap the benefits of their initial investments.
- **Difficulty modifying traditional cropping practices** that are deeply rooted in the society (e.g. tillage).
- **The lack of a favourable economic environment:** DMC dissemination and adoption is always faster and more sustainable on underprivileged family smallholdings in developing countries if they are supported by dynamic large-scale modern mechanised farms that can provide them with inputs, advice and training, while also marketing their crops (e.g. in southern Brazilian states).

FACTORS CONDUCIVE TO DMC DEVELOPMENT

Some key factors for trouble-free adoption of DMCs by farmers have been identified:

- **DMC systems must be economically and technically efficient.**
- **Awareness-boosting demonstrations** are required at experimental “showcase” sites with farmer participation.
- **Economic benefits of DMCs should be clear:** DMCs should rapidly generate solid income and interesting benefits for farmers.
- **Benefits should be substantial enough** to convince farmers to change their current farming practices.
- **All subsector and development stakeholders should be taken into account** in the target region, especially those in the private sector.
- **DMC adoption should be supervised and monitored** by an advisory-support service for a relatively long period (several years).
- **Access to information, training and education** should be facilitated.

The political environment is also a key to successful DMC dissemination/adoption—farmers must be free to form associations, disseminate and communicate. National agricultural and environmental legislation can be highly influential (e.g. government eco-conservation incentives have been quite successful in promoting the adoption of no-till cropping practices by farmers in the United States). ■



SUCCESS FACTORS IN BRAZIL



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A few other factors that ensure successful DMC adoption are as follows:

- **A high degree of dissemination between farmers** through no-till farming associations and by providing farmers

with access to top quality practical manuals.

- **Brazilian farmers have to be very competitive** on the world market since they receive no subsidies. To ensure wide DMC dissemination, it is essential to set up an effective research/extension (demonstration and dissemination)/farmers' organization coalition.
- **Interdisciplinary conservation agriculture networks are needed.**
- **Finally, more rational and environment-friendly use of chemical products, especially herbicides, is crucial.** This is a key to successful DMC adoption.



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Test your knowledge on DMCs...

Note: several answers may be possible.

e. p. Tivet

TEST

1. What is agroecology?

- a. An action, research and engineering trend that does not separate ecology and agriculture, applied to production systems and subsectors to promote sustainable development and environmental conservation.
- b. Agriculture that does not involve the use of synthetic chemical inputs.
- c. A cropping system in which seeds are planted directly in untilled soil.

2. In what country was the direct seeding concept founded?

- a. Argentina
- b. USA
- c. Canada
- d. Brazil

3. What basic principles underlie DMC?

- a. The soil is never tilled.
- b. No pesticides are used.
- c. The soil is permanently protected by plant cover.
- d. Perennial crops are always grown in association with annual crops.

4. What are the agricultural benefits of DMC?

- a. Threefold higher yields in less than 2 years.
- b. Erosion halted.
- c. Better water supply.

5. Which of the following economic benefits apply to DMC?

- a. Reduction of production costs.
- b. Income diversification.
- c. Doubled yields.

6. How do simplified cropping techniques (SCT) differ from DMC?

- a. The soil is left bare under SCT.
- b. The soil surface may be scraped under SCT.
- c. Tillage is carried out under SCT.
- d. There are no crop rotations under SCT.

7. How can DMC help in combating desertification?

- a. By promoting reforestation of relatively infertile soils.
- b. By halting erosion and preserving soil moisture.
- c. By boosting the organic matter content of the soil.

8. What mean potential carbon sequestration level can be achieved in DMC soils?

- a. 1-2 t/ha/year of carbon over 10-15 years.
- b. 4-8 t/ha/year of carbon over 5-10 years.
- c. 0.1-0.5 t/ha/year of carbon over 10-15 years.

9. How do DMCs enhance carbon sequestration?

- a. By eliminating tillage, which accelerates carbon release.
- b. By reducing mechanized work and thus fuel consumption.
- c. By increasing organic matter contents of the soil via the use of cover plants.
- d. By settling shifting agriculture, thus preserving forests.

10. What is one action research concept?

- a. It is performed mainly in laboratories.
- b. It involves farmers during all research stages.
- c. Researchers from both developed and developing countries are involved.

11. What is the main factor that prompts farmers to adopt DMC?

- a. Erosion control.
- b. Enhanced soil fertility.
- c. Economic benefits.

12. Which of the following environmental impacts could be expected if DMC was adopted throughout an agrarian region?

- a. Increased water infiltration and higher water table levels.
- b. Reforestation of large areas.
- c. Local enhancement of carbon sequestration, thus reducing the greenhouse effect.



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13. How does DMC enhance water management?

- a. Eliminating surface runoff.
- b. Limiting evaporation.
- c. Increasing soil water retention.
- d. Crops are more drought resistant.

14. How does DMC contribute to biodiversity preservation?

- a. The plant cover provides a good habitat for living organisms.
- b. By increasing the organic matter content of the soil (basis of the food chain).
- c. By providing a source of food for wildlife.

15. What is one of the main constraints to large-scale DMC dissemination in northern Cameroon?

- a. The low annual rainfall.
- b. The varied topography.
- c. Common grazing rights and herder/farmer relationships.

16. What are the main constraints to large-scale DMC dissemination in Laos?

- a. The overall forest environment in Laos.
- b. The access to credit and mechanization.
- c. Rice cropping is by far the main form of agriculture.
- d. The dispersion of agriculture and training of extension agents.

17. What are the features of SEBOTA rice?

- a. It can be grown under all water regimes, from rain-fed to irrigated.
- b. It yields threefold more rice than conventional varieties.
- c. It is mainly resistant to blast, which is the main cryptogamian disease of rice.

18. What is one of the key factors underlying DMC adoption by Tunisian farmers?

- a. Higher yielding cereal varieties.
- b. Water and soil conservation measures.
- c. An adapted seeder.

19. What are 'nutrient pumps'?

- a. Cover plant species with powerful root systems that tap deep minerals.
- b. Especially efficient fertilizers.
- c. Plant species that promote growth synergy with the main crop.

20. How do DMCs decompact sealed soils?

- a. By preliminary shallow tillage before sowing if necessary.
- b. Through the powerful root systems of cover plants, which enhance soil porosity.
- c. By erosion of the soil surface.

Answers

1a (see 1.6) • 2b (see 1.2) • 3a and c (see 1.3) • 4 b and c (see 1.4) • 5 a and b (see 1.5) • 6 a and b (see 1.6) • 7 b and c (see 2.1) • 8a (see 2.8) • 9a, b, c and d (see 2.3) • 10b and c (see 4.1) • 11c (see 4.2) • 12a and c (see 1.4) • 13a, b and c (see 1.4) • 14a and b (see 1.4 and 2.2) • 15c (see 3.1) • 16a and d (see 3.2) • 17a and c (see 3.3) • 18c (see 3.4) • 19a (see 1.3) • 20a and b (see 1.3 and 1.4)

Websites

(list drawn up in 2006)

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WEBSITES

SITES WORLDWIDE

- Food and Agriculture Organization of the United Nations (FAO, Conservation Agriculture)

www.fao.org/ag/ca/

- Site of Rolf Derpsch

www.rolf-derpsch.com

- CIRAD (Agroecology Network)

<http://agroecologie.cirad.fr/index.php?langue=en>

- Ecoport Conservation Agriculture

<http://ca.ecoport.org>

- New Agriculturist (site of Theodor Friedrich)

www.new-agri.co.uk/00-4/perspect.html

SITES CONCERNING AFRICA

- African Conservation Tillage network (ACT)

www.act.org.zw and www.fao.org/act-network

- Animal Traction Network for Eastern and Southern Africa (ATNESA)

www.ATNESA.org

- Center for Cover Crops Information and Seed exchange in Africa (CIEPCA)

http://ppathw3.cals.cornell.edu/mba_project/CIEPCA/home.html

- Groupement Semis Direct de Madagascar (GSDM)

<http://iarivo.cirad.fr/doc/scv/gsdm.pdf>

SITES CONCERNING LATIN AMERICA

- Centro Internacional de Información sobre cultivos de Cobertura (CIDICCO)

www.cidicco.hn

- Latin American Consortium on Agroecology and Sustainability Development (CLADES)

www.cnr.berkeley.edu/~agroeco3/clades.html

- Red Latino-Americana de Agricultura Sostenible (RELACO)

www.fao.org/ag/ags/agse/6to/relaco/relaco.htm

- Confederacion de Asociaciones Americanas para la Agricultura Sustentable (CAAPAS)

www.caapas.org

- Asociación Argentina de Productores en Siembra Directa (Argentine, AAPRESID)

www.aapresid.org.ar



- CAMPO (Argentina)

www.e-campo.com

- Federação Brasileira de Plantio Direto na Palha (Brazil, FEBRAPDP)

www.febrapdp.org.br

- Associação de Plantio Direto do Cerrado (Brazil, APDC)

www.apdc.com.br

- Institut Agronomique du Paraná (Brazil, IAPAR)

www.iapar.br

- Fundação Agrisus de Agricultura Sustentável (Brazil, AGRISUS)

www.agrisus.org.br

- Empresa de Pesquisa/Agropecuária e Extensão Rural de Santa Catarina (Brazil, EPAGRI)

www.epagri.rct-sc.br

- Plataforma Plantio Direto de l'Empresa Brasileira de Pesquisa Agropecuária (Brazil, EMBRAPA)

www22.sede.embrapa.br/plantiodireto/

- REVISTA 'Plantio Direto' (Brazil)

www.plantiodireto.com.br

- Cooperativa dos Agricultores de Plantio direto (Brazil, COOPLANTIO)

www.cooplantio.com.br

SITES CONCERNING AUSTRALIA

- Western Australian No-Till Farmers Association (WANTFA)

www.wantfa.com.au

- South Australian No-Till Farmers Association (SANTFA)

www.santfa.com.au

- Victoria No-Till Farmers Association (VNTFA)

www.vicnotill.com.au/links.htm

- Central West Conservation Farming Association (CWCFA)

www.confarming.org.au

- Mallee Sustainable Farming Inc. (MSF)

www.msfp.org.au

- Conservation farmers Inc. (CFI)

www.cfi.org.au

- Bill Crabtree (DMC researcher)

www.no-till.com.au

SITES CONCERNING ASIA

- Rice-Wheat Consortium for Indo Gangetic Plains (RWC)

www.rwc.cgiar.org

- Site of Peter Hobbs (researcher focusing on Southeast Asia)

www.css.cornell.edu/faculty/hobbs

SITES CONCERNING NORTH AMERICA

- The New Farm (Rodale institute, Pennsylvania, USA)

www.newfarm.org

- Kansas Crop Residue Management Alliance (USA)

www.residue.org

- National Sustainable Agriculture Information Service (ATTRA, USA)

www.attra.org

- Sustainable Agriculture Research and Education (USDA-SARE, USA)

www.sare.org

- Natural Resources Conservation Services, North Carolina (NRCS, USA) and its newsletter (Soil Quality Newsletter)

www.nc.nrcs.usda.gov/programs/CRP/

www.nc.nrcs.usda.gov/technical/techref/soilqualitynewsletter.html

- South Dakota No-till Association (USA)

www.sdnottill.com

- Pacific Northwest Direct seed Association (USA)

www.directseed.org

- No-till Farmer (USA)

www.lesspub.com/cgi-bin/site.pl?ntf/index

- USDA-ARS Conservation System Research (USA)

www.ars.usda.gov/main/docs.htm?docid=6502

- No-till on the plains (USA)

www.notill.org

- Dakota Lakes Research Farm (USA)

www.dakotalakes.com

- Southern Conservation Tillage Systems conference (SCTSC, USA)

www.ag.auburn.edu/aux/nsdl/sctcsa

- Manitoba – North Dakota Zero Tillage Farmers Association (Canada)

www.mandakzerotill.org

- Saskatchewan Soil Conservation Association (SSCA, Canada)

<http://ssca.usask.ca>

- Alberta Reduced tillage Association (Canada)

www.reducedtillage.ca

- Prairie Agriculture Research Initiative. Decision support system (PARI, Canada)

<http://paridss.usask.ca/index.html?factbook/soilcrop/prem.html>

SITES CONCERNING EUROPE

- European Conservation Agriculture Federation (ECAAF)

www.ecaf.org

- Belgian Association in Research Application on Conservation Agriculture (BARACA, Belgium)

www.baraca.be

- Foreningen for reduceret jordbearbejdning (FRDK, Denmark)

www.frdk.dk

- Asociación Española Agricultura de Conservación / Suelos vivos (AEAC/SV, Spain)

www.aeac-sv.org/html/actividades.html

- Association pour la Promotion d'une Agriculture Durable (APAD, France)

www.apad.asso.fr

- Fondation Nationale pour une Agriculture de Conservation des Sols (FNACS, France)

www.isasite.net/FNACS

- Bretagne, Agriculture, Sol et Environnement (BASE, France)

<http://pageperso.aol.fr/baseagrisol/mapage/associations.html>

- Agriculture de Conservation (France)

www.agriculture-de-conservation.com

- Soil Management Initiative (SMI, UK)

www.smi.org.uk

- New Agriculturist on line (UK)

www.new-agri.co.uk/00-4/perspect.html

- Associazione Italiana per la Gestione Agronomica del Suelo (A.I.G.A.Co.S., Italy)

www.aigacos.it

- Swiss No-Till (Switzerland)

www.no-till.ch

- Associação Portuguesa de Mobilização de Conservação do Solo (APOSOLO, Portugal)

www.aposolo.pt

Glossary

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GLOSSARY

- **Adventitious plant:** This is a noncrop plant that has not been intentionally propagated. These are commonly called weeds.
- **Allelopathy:** Competition between plants of different species via toxic substances excreted by the roots or leaves.
- **Atmospheric nitrogen fixation:** A set of chemical and biological processes that extract atmospheric nitrogen to transform it either into ammonia or nitrate that can be assimilated by plants or into immobilized organic nitrogen.
- **Autotroph:** This is an organism that only feeds on mineral substances in the soil, air or water. Such organisms obtain energy directly from the sun or through oxidation of some simple elements or compounds. Such organisms can utilize airborne carbon dioxide as a source of carbon through the chlorophyll it contains and via photosynthesis.
- **Conventional agriculture (conventional cropping system or practice):** Agriculture in a given region in which farmers use the most common traditional technical interventions, which is often tillage.
- **Externality:** This is the positive or negative consequence of the activity of one or several economic stakeholders on other economic stakeholders and which the market does not take into account. One typical example is an industrial company that freely emits toxic smoke into the atmosphere that has detrimental effects on the health of other economic stakeholders, who in turn pay the cost.
- **Heterotroph:** An organism that feeds on organic substances for nourishment and growth.
- **Leaching:** Slow water percolation through the soil, accompanied by dissolution of solid materials within the soil.
- **Mineral recycling:** Biological upwelling (via roots and plant biomass that falls on the surface) and reuse, via mineralization, of the fresh organic matter spread during the cropping season, of soil nutrients that would otherwise be lost by runoff or leaching.
- **Newly cleared area:** An area that is just being developed on the fringe of a natural zone.
- **Nonselective nonresidual herbicide:** A nonselective herbicide can, when used at recommended dosages, destroy all vegetation prior to sowing a crop. It is nonresidual if it is no longer active after its initial knockdown effect.
- **Nozzle:** A one- or multi-piece tool through which a slurry or other liquid is sprayed. There are different types, e.g. centrifugal, flat spray, straight stream, deflector, etc.
- **Relay crop:** Short-cycle crop that supplements the main crop harvest during the same cropping season.
- **Ridging:** An operation that involves piling soil around separate crop plants or in rows (e.g. potatoes).
- **Row intercropping:** Growing crops between rows of another crop.
- **Scarification:** Soil tillage using a rigid-tine cultivator whereby the soil is not turned over.
- **Shallow ploughing:** An agricultural operation that is carried out after harvest to partially bury stubble and weeds via surface scraping, and to break up the crust on the soil surface in order to hamper evaporation of the underlying moisture.
- **Slash-and-burn agriculture/Shifting agriculture:** Shifting agriculture in intertropical forest ecosystems. Recurrent clearing and burning of the forest for the purposes of cropping for 2-4 years, followed by bush fallows for a varying period (around 10 years or more) to enable soil fertility recovery, followed by a cropping cycle, and so on.
- **Soil horizon:** A soil layer that is relatively parallel to the surface and differs from the generally linked adjacent layers by its morphological, physical, chemical or biological features (e.g. colour, number and type of organisms present, structure, texture, consistency, etc.).
- **Soil porosity:** Ratio of the total void space volume in the soil relative to the total bulk soil volume.
- **Systems approach:** An analytical approach that involves assessing a complex object like a system composed of elements that interact with each other.
- **Water retention capacity:** The proportion (in weight or volume) of water that a soil can retain after being saturated with water and then dried.
- **Weed:** see 'Adventitious plant'

Acronyms and abbreviations

e. F. Tivet

ACRONYMS

AAP	Agroecology action plan
AFD	French Development Agency / <i>Agence Française de Développement</i>
ANAE	<i>Agence Nationale d'Action Environnementale</i> , Madagascar
ARC	Agricultural Research Centre, Laos
AVSF	Agronomists and Veterinarians without Borders
BRL	<i>Bas-Rhône Languedoc</i> , France
CA	Conservation agriculture
CIRAD	Agricultural Research Centre for International Development, France / <i>Centre de coopération internationale en recherche agronomique pour le développement</i>
CPC	Committee for Planning and Cooperation, Laos
CT	Conservation tillage
CTC	Technical Centre of Cereals, Tunisia / <i>Centre Technique des Céréales</i>
DGCID	Directorate for Development Policies, France / <i>Direction Générale de la Coopération Internationale et du Développement</i>
DMC	Direct seeding mulch-based cropping systems
DPGT	<i>Projet Développement Paysannal et Gestion de Terroir</i> , Cameroon
DT	Tunisian dinar
EMBRAPA	<i>Empresa Brasileira de Pesquisa Agropecuária</i> , Brazil
ESA	' <i>Eau Sol Arbre</i> ' project, Cameroon
ESAK	Higher School of Agriculture of Kef, Tunisia / <i>École Supérieure d'Agriculture du Kef</i>
FAFIALA	<i>Centre d'expérimentation et de diffusion pour la gestion paysanne des tanety</i> , Madagascar
FAO	Food and Agriculture Organization of the United Nations, Italy
FFEM	French Global Environment Facility / <i>Fonds Français pour l'Environnement Mondial</i>
FIFAMANOR	<i>Fiompiana Fambolena Malagasy Norveziana</i> , Madagascar
FOFIFA	National Center for Research Applied to Rural Development, Madagascar / <i>Institut National de la Recherche Appliquée au Développement Rural Malgache</i>
GHG	Greenhouse gas
GNP	Gross national product
GRET	<i>Groupe de Recherche et d'Échanges Technologiques</i> , France
GSDM	Direct seeding group of Madagascar / <i>Groupement Semis Direct à Madagascar</i>
INTA	<i>Instituto Nacional de Tecnología Agropecuaria</i> , Argentina
IRAD	<i>Institut de Recherche Agricole pour le Développement</i> , Cameroon
LAMS	<i>Laboratoire d'analyses et de microbiologie des sols</i> , France
MAEE	French Ministry of Foreign and European Affairs, France / <i>Ministère des Affaires étrangères et européennes</i>
NAFRI	National Agriculture and Forestry Research Institute, Laos
NTT	No-tillage techniques
PASS-PCADR	<i>Point d'Application du Sud de la Province de Sayaboury</i> , Laos
PRODESSA	Xayabury Rural Development Project, Laos
PRONAE	National Agroecology Programme, Laos
PSZ	Priority Solidarity Zone
PTA	Transversal Programme for Monitoring and Support
SCT	Simplified cropping techniques
SD Mad	<i>Semis Direct Madagascar</i>
SODECOTON	<i>Société de Développement du Coton au Cameroun</i>
TAFA	<i>Tany sy Fampandrosoana</i> , Madagascar
USA	United States of America
USD	US dollar
VERAMA	<i>Les Vergers d'Anacardes de Masiloaka</i> , Madagascar
WANTFA	Western Australian No-Tillage Farmers Association
WSC	Water and soil conservation



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RÉSUMÉ

Le semis direct sur couverture végétale permanente (SCV) est actuellement une des solutions qui s'offre aux économies paysannes, notamment dans les pays du Sud, pour sortir de la spirale de la dégradation de leur environnement et des faibles niveaux de compétitivité de leurs productions. Ces techniques ont fait leurs preuves de leurs nombreux intérêts, aussi bien agronomiques, qu'environnementaux et économiques, dans des contextes très différents (agriculture mécanisée, petites économies familiales). Ces systèmes de culture alternatifs font ainsi naître dans de nombreux pays l'espoir d'aller dans le sens d'un développement agricole durable à un niveau de productivité élevé. Leur diffusion à grande échelle dans de nouveaux pays soulève toutefois certains problèmes comme celui pour l'agriculteur de passer d'une agriculture de tradition à une agriculture d'innovation. Cependant les avantages de la mise en oeuvre de ces pratiques se révèlent assez vite aux agriculteurs : économie de main d'oeuvre, des intrants, accroissement des résultats agronomiques, moindre sensibilité aux aléas climatiques... L'objet de ce dossier est de présenter de façon synthétique et dans un langage accessible à tous non seulement les principes généraux à la base des SCV, mais aussi les impacts bénéfiques agronomiques, écologiques et socio-économiques. Des projets réussis de mise en oeuvre de SCV en Tunisie, Madagascar, Laos, Cameroun, dans le cadre du programme transversal d'accompagnement (PTA) mené par l'AFD et ses partenaires, sont également présentés pour illustrer le dossier de cas concrets sur le terrain.

ABSTRACT

Direct-seeding mulch-based cropping systems (DMC) now provide an interesting cost-effective alternative for farmers, especially in developing countries, while alleviating environmental degradation and enhancing farmers' production competitiveness. DMC techniques have many agronomic, environmental and economic benefits that have proven effective in diverse settings (mechanized farming, smallholdings). These alternative cropping systems give hope to many countries for sustainable and highly productive agricultural development. Some problems may arise during large-scale DMC dissemination in new countries, e.g. the difficulty for farmers to switch from traditional to innovative farming practices. Farmers, however, soon become aware of the advantages of this new farming strategy—labour and input savings, increased agricultural performance, lower vulnerability to climatic hazards, etc. This document provides a clearly worded summary of key DMC principles, while also outlining the positive agricultural, ecological and socioeconomic impacts. Field cases of successful DMC implementations in Tunisia, Madagascar, Laos and Cameroon within the framework of the Transversal Program for Monitoring and Support (PTA), coordinated by AFD and partners, are also presented.