CSFD

Les dossiers thématiques

Issue 4

Combating desertification through direct seeding mulch-based cropping systems (DMC)

AGROPOLIS INTERNATIONAL

CSFD

Comité Scientifique Français de la Désertification
French Scientific Committee on Desertification

Les dossiers thématiques du CSFD
Issue 4

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French Scientific Committee on Desertification

The creation in 1997 of the French Scientific Committee on Desertification (CSFD) has met two concerns of the Ministries in charge of the United Nations Convention to Combat Desertification. First, CSFD materialises the will to involve the French scientific community versed in desertification, land degradation, and development of arid, semi-arid and sub-humid areas, in generating knowledge as well as guiding and advising the policy makers and actors associated in this combat. Its other aim is to strengthen the position of this French community within the international context. In order to meet such expectations, CSFD is meant to be a driving force regarding analysis and assessment, prediction and monitoring, information and promotion. Within French delegations, CSFD also takes part in the various statutory meetings of the organs of the United Nations Convention to Combat Desertification: Conference of the Parties (CoP), Committee on Science and Technology (CST), Committee for the Review of the Implementation of the Convention. It also participates in meetings of European and international scope.

CSFD includes a score of members and a President, who are appointed *intuitu personae* by the Minister for Research, and come from various specialities of the main relevant institutions and universities. CSFD is managed and hosted by the Agropolis International that gathers, in the French town of Montpellier and Languedoc-Roussillon region, a large scientific community specialised in agriculture, food and environment of tropical and Mediterranean countries. The Committee acts as an independent advisory organ; it has neither decision-making powers nor legal status.

Its operating budget is financed by subsidies from the French Ministries of Foreign Affairs and for Ecology and Sustainable Development. CSFD members participate voluntarily to its activities, as a contribution from the Ministry for Research.

More about CSFD:
www.csf-desertification.org

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Foreword

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Mankind is now confronted with an issue of worldwide concern, i.e. desertification, which is both a natural phenomenon and a process induced by human activities. Our planet and natural ecosystems have never been so degraded by our presence. Long considered as a local problem, desertification is now a global issue that affects us all, including scientists, decision-makers, citizens from both the South and North. Within this setting, it is urgent to boost the awareness of civil society to convince it to get involved. People must first be given the elements necessary to better understand the desertification phenomenon and the concerns. Everyone should have access to relevant scientific knowledge in a readily understandable language and format. Within this scope, the French Scientific Committee on Desertification has decided to launch a new series entitled *"Les dossiers thématiques du CSFD"*, which is designed to provide sound scientific information on desertification, its implications and stakes. This series is intended for policy makers and advisers from the North and South, in addition to the general public and scientific journalists involved in development and the environment. It also aims at providing teachers, trainers and trainees with additional information on various associated fields. Lastly, it endeavours to help disseminate knowledge on the combat against desertification, land degradation, and poverty to stakeholders such as representatives of professional, non-governmental, and international solidarity organisations.

A dozen reports are devoted to different themes such as biodiversity, climate change, pastoralism, remote sensing, etc., in order to take stock of current knowledge on these various subjects. The goal is also to set out ideological and new concept debates, including controversial issues; to expound widely used methodologies and results derived from a number of projects; and lastly to supply operational and intellectual references, addresses and useful websites.

These reports are to be broadly circulated, especially within the countries most affected by desertification, by e-mail (upon request), through our website, and in print. Your feedback and suggestions will be much appreciated! Editing, production and distribution of *"Les dossiers thématiques du CSFD"* are fully supported by this Committee thanks to the backing of relevant French Ministries. The opinions expressed in these reports are endorsed by the Committee.

Preamble

Jean-Yves Grosclaude
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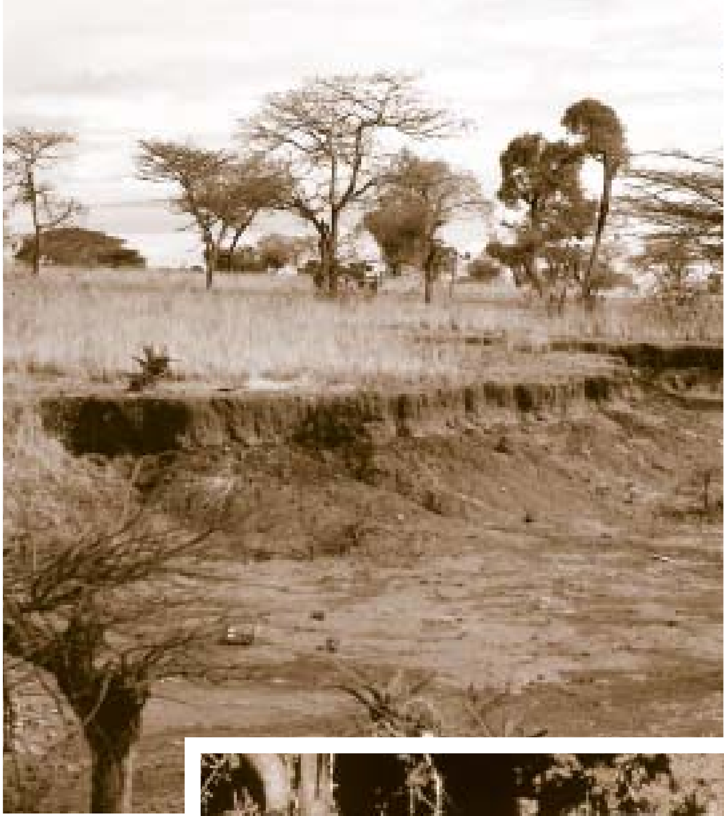
For decades, farmers in many regions have had to deal with serious soil erosion problems—water erosion during every rainfall, wind erosion, which blows away the soil and generates dust clouds, with an impact that reaches far beyond the initial areas. Everyone remembers the dust bowl process, which darkened the skies over the grain fields of the Great Plains in USA and Canada during the 1930s. Everyone also knows about the devastating effects of erosion on the Loess Plateau in China. Excessive tillage, scarce and poorly distributed water, much of which is lost via runoff, has prompted research on alternative cropping systems, designed especially to stall erosion and runoff, promote rainwater infiltration and offset climatic hazards.

In the 1960s, this gave rise to farming practices combining two concepts: minimal 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 and Australia. It subsequently took root in Asia, Europe (including France), and then Africa and Madagascar. Now more than 90 million ha are cultivated without tillage and direct seeding on mulch. In the 1980s, in the Brazilian *cerrados* and small family farming areas, CIRAD and its Brazilian partners managed to adapt direct seeding principles for application in tropical farming conditions. This has renewed the hopes of smallholders, for whom the soil is a farming resource that has to be sustainably preserved.

These new practices represent more than just a set of techniques, they call for a real change of spirit, because ploughing—a historical mainstay of agriculture—must be abandoned. Research is currently under way, especially in North Africa (Tunisia), sub-Saharan Africa (Cameroon), Madagascar, Vietnam, Laos and Cambodia. For almost 10 years, AFD (French Development Agency), FGEF (French Global Environment Facility) and MAE (French Ministry of Foreign Affaires) have been backing the process of adaptation and dissemination of this "sustainable agriculture", within the framework of rural development projects carried out under a range of agroecological and socioeconomic conditions. This novel agricultural approach brings a solution that is especially suitable for farming in fragile ecosystems with a high risk of desertification.

This 4th *Dossier thématique du CSFD* clearly showcases direct seeding mulch-based cropping systems, including the challenges, difficulties and prospects. I am sure that many readers will be won over, since these new systems represent a keystone for sustainable agricultural development—preserving natural resources, which nurture all rural activities in developing countries.



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New farming practices needed in regions affected by desertification

Desertification has a serious impact on water, soils, **biodiversity, agrarian systems,** and in turn on the people who live off the services provided by **agroecosystems**. Climate change has been worsening in the 21st century, thus broadening the range of desertification, environmental **degradation processes** in arid, semiarid and subhumid-dry regions. Family farms in Southern countries will have to adapt—technically, economically and strategically—to be able to survive.

The soil is often the only capital that farmers have in these regions, and this resource is essential to the functioning and **resilience** of agroecosystems: it should thus be preserved and enhanced. Water is a scarce and uncertain resource in countries affected by desertification: most of it disappears via runoff and evaporation. It should be preserved to benefit soil-plant systems, thus enhancing plant **biomass** production.

Current agricultural systems (combined with livestock farming) are not very productive or diversified, and crop yields are highly irregular in semiarid and subhumid environments. Rural communities are barely able to live off these systems, so malnutrition and endemic

Glossary

Action research: Participative applied research involving development stakeholders and farmers.

Agroecology: A current research and engineering stream of thought and action whereby production systems and subsectors are approached from a joint ecological and agricultural perspective to promote sustainable development and environmental protection.

Agroecosystem: An ecosystem that is utilised for agricultural production.

Biodiversity: Biological diversity, or biodiversity, refers to the variety or variability of all living organisms. This includes genetic variability within species and their populations, the diversity of associated species complexes and their interactions, and that of ecological processes they affect or with which they are involved (IUCN definition, 1988).

Biomass: Total mass of living cells from a given site relative to the area or volume.

Degradation: This term generally means “slow destruction” or adverse change (in a scope and setting to be specified: for a soil, this could involve a loss of biodiversity and resilience, leading to structural breakdown), in a soil or landform, of various processes and a change in environmental conditions (climate, vegetation, water regime, humans, etc.) relative to the initial genesis conditions.

Fertility: Ability of a soil to produce under its climate.

Agrarian system: Spatial expression of the association of farmers and techniques implemented by a rural society to fulfil its needs.

Productivity: Potential ability of an organism (plant or animal) to provide a certain amount of a specific product (whole plants, fruit, seeds, fodder, fibre, oil, wood, milk, meat, wool, etc.) relative to a spatial or temporal unit.

Resilience: Ability of a system to withstand disturbances in its structure and/or functioning and, when these are overcome, to get back to a state that is comparable to the initial situation (Ramade, 1993). In summary, it is the ability to buffer disturbances.

Eroded landscape. Neghelle. Southern Rift Valley, Ethiopia. © M. Raunet

famines are often widespread in these areas. Under such conditions, agro-socioeconomic sustainability seems unfeasible, and farmers, who are struggling to simply fulfil their immediate needs, obviously cannot be very concerned about safeguarding the environment and natural resources.

The rapid degradation trend that comes with desertification can only be stalled by promoting the creation, adaptation, development and large-scale dissemination of new sustainable agrarian systems, especially those combining cropping and livestock production. These positive interventions could be developed and implemented through **action research**, with farmers involved at all development stages.

The principles of an agroecologically-oriented "new agriculture" involving synergetic "soil-water-biomass-biodiversity" interactions are presented in this dossier: direct seeding mulch-based systems (DMC). The underlying principles and features are discussed, along with the direct effects and indirect benefits that both farmers and communities can expect on different scales (field, farm, village land, territory).

Focus

Desertification briefly

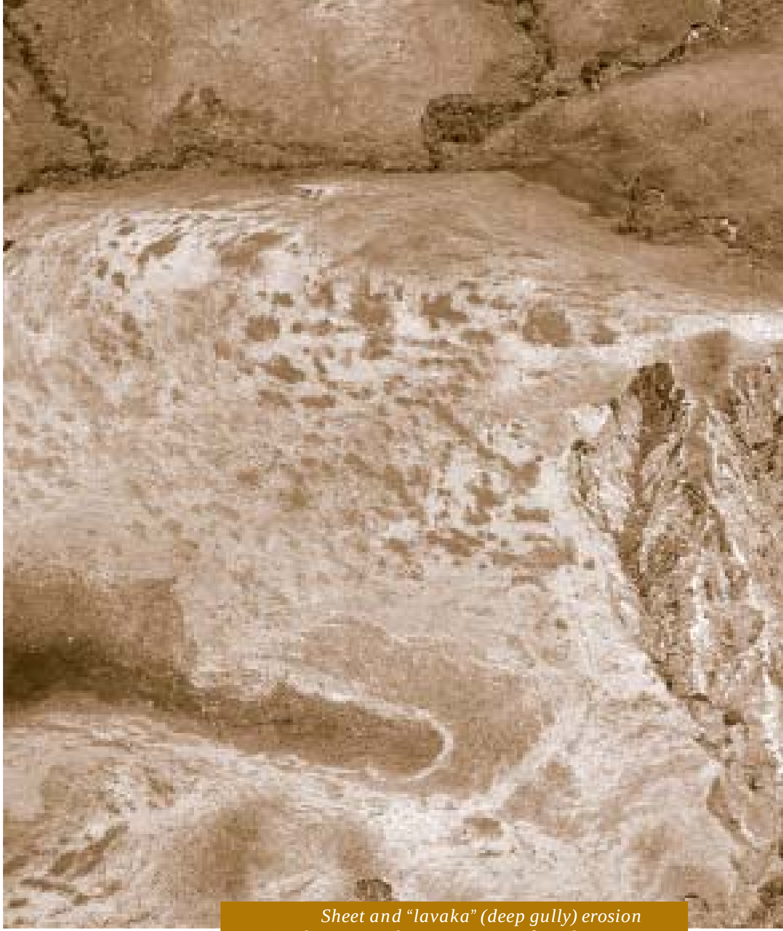
The United Nations Convention to Combat Desertification, drawn up in 1994, defines desertification as *"land desertification in arid, semiarid and dry subhumid areas resulting from several factors, including climatic variations and human activities"*.

The desertification concept, like the closely linked land and ecosystem degradation concept, derives from the overall negative qualitative viewpoint that underlies insidious complex processes (natural and human-induced) which are hard to overcome, combining causes, effects and consequences, along with many feedback loops. These processes have climatic, ecological, agricultural, economic and social aspects—with this latter factor being associated with the use and sharing of scarce resources (wood, fertile soils, water, rangelands, wild game, etc.) because of excessive pressure on these resources or very high human population concentrations.

The desertification concept is also implicitly associated with the drought concept, thus with the scarcity and irregularity of water supplies at crucial times, but also, conversely, with excessive or heavy rainfall that induces damage (waterlogging of crops, destructive mechanical effects, silting of structures, etc.). This land and ecosystem degradation occurs concomitantly to disruption of the ecological balance and involves a reduction in ecosystem **productivity,** i.e. the **fertility** of soils, plant cover, rangelands, biodiversity, etc. In addition, there are ecoclimatic and human dimensions, i.e. excessive anthropogenic pressure, difficulty in living and producing in such ecosystems, risks, poverty, need for adaptation, etc.

Rural people require an adaptive control strategy to overcome this imbalance and degradation, including better risk management and, if possible, a scheme to ensure agroecosystem regeneration and enhanced resilience. The resilience concept is pivotal to the desertification process. Desertification could be considered as equivalent to a loss of resilience resulting from combined ecoclimatic and human stress. Conversely, "backtracking" (regeneration) by human means (e.g. new cropping practices) will result in a resilience gain (recuperation). The resilience of an agroecosystem is the foundation of its sustainability.

Soil and water in desertification conditions



Sheet and "lavaka" (deep gully) erosion in the Hauts-Plateaux region of Madagascar. © M. Raunet

Desertification is not directly associated with annual rainfall levels. The desertification process can, for instance, occur when the soil and vegetation conditions are degraded but there is 1,400 mm of annual precipitation. Desertification is, however, directly linked with the fact that for various reasons (e.g. capped soils) rainfall does not (or no longer does) penetrate into the soil enough to adequately nourish crops, rangelands and natural vegetation.

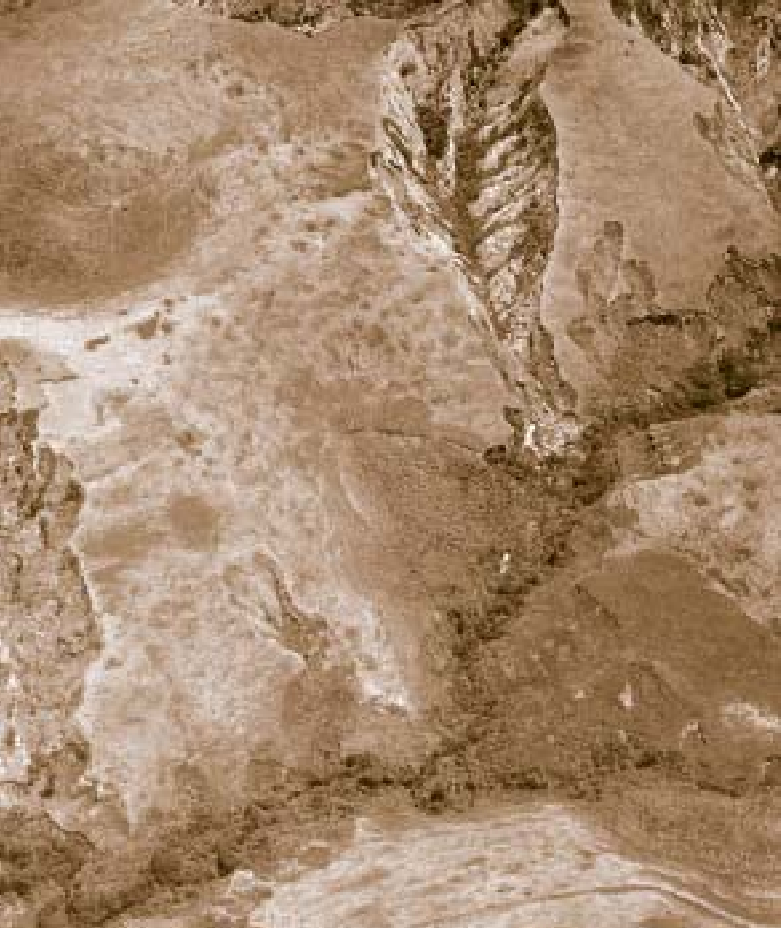
The shortage of water percolating through the soil is mainly due to the physical and organic quality of degraded soils and the low level of plant cover, thus increasing the vulnerability of these soils to climatic stress (e.g. heavy precipitation). This is a typical situation where the causes and effects are mutually involved in a process that has no clear onset. A small-scale (realistic, yet metaphorical) model of this process is the ordered contraction of the vegetation cover in striped bush (vegetation/soil complex alternating shrub thickets and bare areas in a clumped and/or striped pattern) on **glacis** in semiarid regions. These vegetation strips correspond to areas where water infiltrates, and the bare patches are integral **runoff** areas where the desertification process has begun. The functioning of this striped structure, and the way it develops once it begins, are quite well known. Little is known, however, about the onset of the process, how it is triggered or the thresholds beyond which it begins.

Poor, fragile and unproductive soils

In semiarid and subhumid dry, so-called degraded areas, water does not percolate to deep soil horizons because of the poor **soil structure** (so-called continuous or massive structure) due to the extreme lack of organic matter. The soil also has low porosity or is completely sealed close to the surface by **kaolinic** clays, iron oxides and quartz sand which act like solid concrete.

In dry tropical regions, sandy to sandy-loamy soils, which generally have a very low organic matter content (0.3-1% in the top 20 cm layer), to fragile soils with very little structure, are conventionally cropped after scraping and pulverization of the soil surface (tillage to 8-10 cm depth). The soils are then left bare, which makes them even more vulnerable to **sealing** and **sheet erosion**, thus maintaining or even worsening the impact of desertification.

Leaching is very common to 20-40 cm depth, corresponding to the maximal water percolation depth. In this layer, which is sandier or loamier than the underlying layer, and waterlogged during heavy rainfall, the water flows "hypodermically" in a lateral direction, leading to the formation of a small **perched water layer** which surfaces quickly to merge with the heavy surface runoff. This causes temporary waterlogging of root systems, which are asphyxiated, just at the time when they are also hampered by drought if it has not rained for a week! These beige-, grey- or pink-coloured soils are called "leached **tropical ferruginous soils**". When the leached layer settles, through a sudden discontinuity, on a more clayey and compact substrate that water and roots cannot penetrate, these are called **planosols** (like the famous sterile degraded *hardé* soils of northern Cameroon).



Focus

Striped bush, a striking vegetation facies common to the Sahel

The "striped bush" ecosystem is typical of the vegetation found on relatively regular landscapes along glacis, with slopes of less than 2%, in the Sahel or along the northern edges of Sudanian-Sahelian regions. This ecosystem includes strips or arc-shaped areas of vegetation, often regularly-spaced shrub thickets of variable width growing parallel to relatively continuous contour lines. These vegetation strips are interspersed with bare strips of land with very little plant cover -so it is also called "contracted vegetation". These ecosystems can be structured in lines, arcs or rosettes. This type of vegetation is also found beyond Africa, in other semiarid environments in Australia, Mexico, Madagascar, etc.

This type of vegetation adaptation and contraction is noted in areas under low rainfall regimes (300-700 mm/year) but where violent sporadic storms occur with subsequent intense sheet runoff. These vegetation stands are the result of a tradeoff between the soil, climate, vegetation and human activities. The striped stands offset the low rainfall conditions and enable the vegetation to develop under *a priori* unfavourable ecological conditions (300-400 mm/year of rainfall). Contracted systems common to unfavourable climatic areas recreate, by their structure, ecological conditions resembling those that occur in more favourable areas that receive 800 mm/year of rainfall! These higher productivity levels go against the opinion that these systems have developed as a response to environmental degradation (Ichaou, 2000). After onset of the process, it proceeds via positive **feedback** (with trapping of plant debris, sediment and seeds), thus inducing auto-reinforcement of the striped shrub stands.

Stripped bush on the Sofia Bangou plateau near Banizoumbou (60 km east of Niamey, Niger).
The soil is ancient hardpan laterite with a thin layer of very clayey loose soil (0-60 cm thick), with low organic matter content in bare strips and a high content in strips of vegetation.

Focus

Degradation of intertropical soils: farming practices have to change!

Land began seriously degrading in the tropics and subtropics in the 1960s as a result of the population boom and land saturation, with a concomitant shortening of fallow periods in savanna areas and forest reconstruction in humid areas. This degradation included all types of erosion, compaction and hardsetting, leaching, acidification, organic matter loss, uncontrollable weed invasion, etc., thus resulting in overall degradation of soil fertility. This situation will undoubtedly worsen yearly due to climate change if effective solutions are not found. Despite increased awareness on this process, initiatives required under suitable socioeconomic conditions to overcome this feedback-type soil degradation spiral have not been applied on a large scale.

Agricultural sustainability is inevitably linked with the sustainability of soil fertility—which is essential for crop production. Soil protection is thus a major economic challenge. Striving to preserve and improve soils helps fight poverty. Paradoxically, economists and policymakers are often unable to assess a soil before or after cultivation, or to forecast the outcome after a certain period of use. Development economists classify the soil under general non-renewable natural resource management issues, despite the fact that it is theoretically a lasting resource, in contrast with other resources (water, forests, fish, rangelands, etc.). The soil can be assessed according to its quality, as much or even more than its quantity. This quality is called "fertility", which humans can degrade or regenerate.

It should be kept in mind that farmers do not degrade soil fertility by pleasure, lack of awareness or without realizing it, but unfortunately because they have no other choice. The pressure on the land becomes too heavy and the farmer's plans for the future are dictated by his/her short-term survival needs. Medium and long-term prospects are too remote, especially since the farmer often has no investment potential. In this deadlock situation, farmers of the South will have to change their practices, often drastically, and they should be assisted via development-oriented research. This is top priority.

Gully erosion in a sisal plantation. Rift Valley, Ethiopia.
© M. Raunet

Focus

Nature and hydrologic function of a Sudano-Sahelian soil

A typical soil of Sudano-Sahelian regions in Africa (500-900 mm annual rainfall) or a "duplex soil" in Australia can be represented by the following scheme:

Four successive soil horizons (or levels or materials)

- **0–25 cm:** loamy sand horizon, which is leached and clear, and where most roots are found.
- **25–80 cm:** compact horizon, not very porous, hardsetting and often dry sandy clay containing few roots.
- **80–500 cm:** mottled sandy clay loam alterite, so-called "loose plinthite", moist, with a fluctuating water table.
- **500–2000 cm:** micaceous sandy clay, greenish-grey and plastic, embedded in the so-called "alterite" water table.

Below 2 m: sound bedrock, sometimes with a deep water table in the cracks.

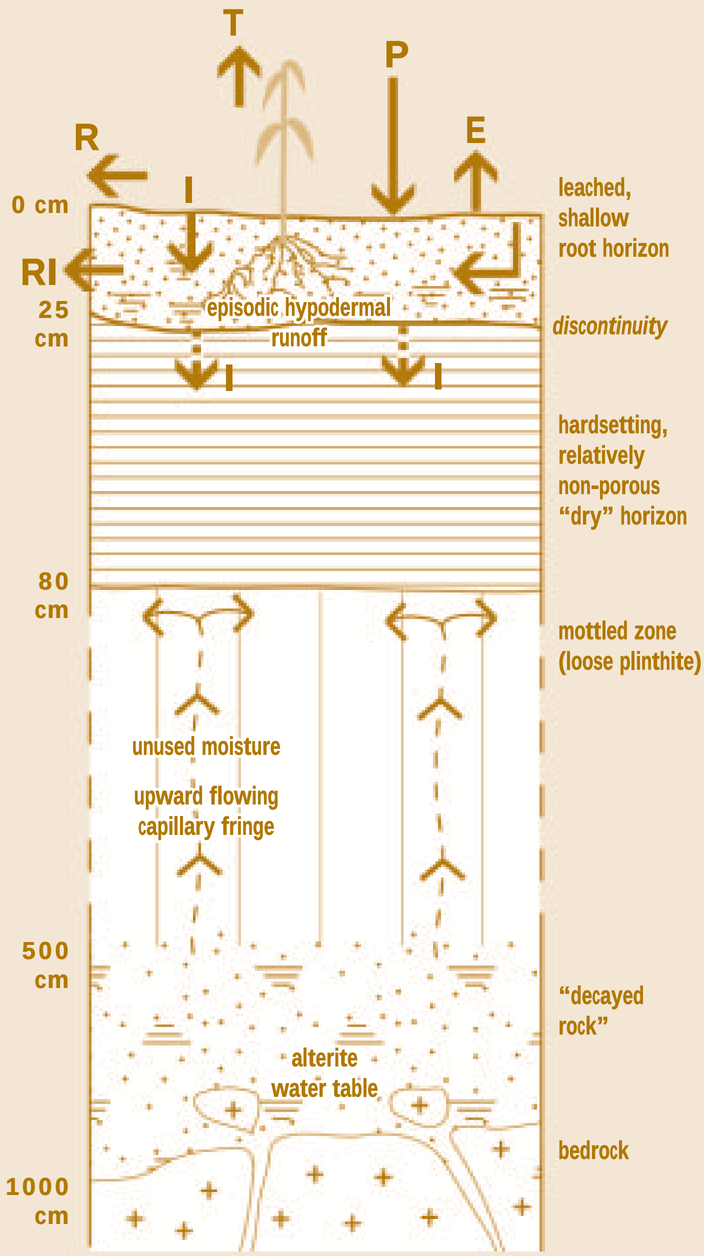
Water flow

In this kind of soil, rainwater percolates downward, while moisture from the water table circulates upward. These two flows are relatively independent and sometimes do not overlap:

- At the surface, precipitation (P) is dispersed via runoff (R), infiltration (I), lateral hypodermic runoff (RI) during the heaviest rainstorms, transpiration (T) and evaporation (E). The sum of (R) and (RI) can represent up to 60% of the rainstorm water.
- In the deep horizons, there is generally an alterite water table that saturates much of the micaceous sandy clay alteration zone, often called "decayed rock", which generally ranges from 10 to 30 m thick. This water table fluctuates from 2 to 10 m deep throughout the year, between the rainy and dry season.

The fluctuation fringe (in the rainy season) or capillary fringe (in the dry season) is located just above the water table, thus moistening the mottled clay alterite layer, or so-called "loose **plinthite**" (as opposed to "indurated plinthite", which is a ferruginous cap resulting from local hardening).

The horizon located at 25-80 cm depth consists of a material that is generally unsuitable for water and roots. It is sandy clay, massive, not very porous, hardsetting, so there is very little water percolation. The upward flowing capillary fringe is blocked at the base for the same reasons. Consequently, the soil is humid (even during the dry season) as of 80-100 cm depth. This moisture therefore does not benefit the cultivated plants whose roots are mostly in the 20-30 cm horizon, despite the fact that they are regularly subjected to water stress in these regions.



Hydric function of a typical soil in Sudano-Sahelian regions where desertification is under way.

E: Evaporation • I: Infiltration
P: Precipitation • R: Runoff
RI: Hypodermic runoff
T: Transpiration

Saline soil. Western Madagascar.
© M. Raunet

An untapped deep water supply

A unique feature of soils in African regions affected by desertification is that they have a deep groundwater supply (generally below 1 m). This moisture is even present in the dry season. However it is unused by crop roots, which are unable to reach this pool because of hardsetting and clogging of the soil horizons at 20-40 and 80-100 cm depth.

This almost permanent, and unfortunately untapped, deep humidity could correspond to the top of a relatively long-standing and regularly fed **capillary fringe** of the **water table** located in alterations of the deep soil horizons. The top of the water table, which ranges from 5 to 15 m depth, often supplies a broad capillary fringe due to the clayey to sandy clay nature of the alterites (bedrock alteration products). This capillary fringe, which cannot cross the sealed soil zone located between 20-40 and 80-100 cm depth, constantly humidifies the subsoil. Some agricultural soil management practices (like DMC) can capture and utilize this moisture.

These sandy-clay soils have a very low water retention capacity in the shallow root zone. Consequently, crop plants and natural rangelands are quickly stressed if rainfall is irregular. Moreover, at least 50% of the rainwater is lost via runoff or lateral flow. This water, which runs off very quickly during heavy rain storms (even more so when there is little vegetation cover), floods lowland areas and can cause serious damage to crops, infrastructures and inhabitants along the way (waterlogging, rushing water).

Soil degradation and human activities

Soil degradation is another induced calamity that affects areas where desertification is under way. In dry regions, **vertisols** (expansive clay soils) often prevail in lowland areas—these are the most fertile soils in such regions. These vertisols are unfortunately often hampered by flooding during the rainy season as a result of the impact of heavy rainfall events and hazards and the poor upstream soil quality. They can, however, sometimes be utilized after the waters recede thanks to the residual humidity in *karé* (vertisols under sorghum crops grown after the floods recede, which is called *muskwari* in northern Cameroon), but they are hard to manage.

The pedological causes described above—along with deforestation, bush fires, depletion of fallow land, overgrazing of rangeland, and livestock trampling, scant plant cover, which denude the land—lead to soil clogging and sealing. Such soils are then directly, and totally or partially, exposed to heavy rainfall and winds (intense runoff, water and/or wind erosion) and heat stress (which upsets the biological activity of the soil). In a vicious circle, these processes further accelerate the deterioration and loss of biodiversity in the soil and environment.

There seems to be a threshold of degradation and denudation (in a patchy or mosaic pattern) beyond which the mechanisms change scale, accelerate and become widespread. One of the most renowned examples of this is the dust bowl that swept across grain fields and blackened the sky, on the Great Plains in USA and Canada in the 1930s. This was a combined result of overuse of soils by **dry farming** (involving worked summer fallows and bare fallows) and drought.

Another consequence of desertification is the formation of saline soils as a result of woodland clearing. Trees have deep roots so they can tap the capillary fringe of the water table and maintain it in the deep horizons. Clearance of these trees and their deep roots by deforestation drives the moisture front upward toward the surface. There is a risk of soil salinization if the underlying material is mineralized. In such cases, the soils are thus no longer suitable for cereal cropping, etc. This is a very common phenomenon in Australia, and on the Great Plains and prairies in North America. It also occurs in Africa, but less frequently.

Focus

The dust bowl in USA, a national disaster caused by excessive tillage

The dust bowl phenomenon that occurred on the semiarid (300-600 mm of rainfall) Midwestern Great Plains in the United States is the most famous case of large-scale wind erosion due to soil degradation. The dust bowl took place in the 1920s, 30s and 40s following excessive use of dry farming practices involving biennial cereal-tilled fallows (so-called summer fallows) rotations. The dust bowl was the setting of John Steinbeck's 1939 novel The *Grapes of Wrath* in which he described the misery and migration of farmers affected by this catastrophic phenomenon.

As of the 1920s, the advent of motorization and the increased power of tractors promoted repeated tillage of fields and led to an increase in the tilled area. 18-month fallowed fields were first burnt after harvesting and then systematically tilled (ploughing and pulverized). The land was thus laid bare so that it would be ready to absorb as much moisture as possible to be utilized by the subsequent cereal crop, which was planted every other year, with the dust or granular mulch created serving to reduce evaporation. The second reason for burning crop residue and repeated tillage was to regularly control water-consuming weeds and clear the soil of pests and diseases. Finally, the last reason put forward was to enhance the release of mineral nitrogen right after the cereal crops were sown. The merits of dry farming have been constantly debated over the years. The experimental, technical and economic results are often conflicting because of the extreme climatic variability in such regions. A difference of 50 mm in rainfall during a season can indeed have a major impact.

The use of this practice since the beginning of the 20th century induced severe wind erosion on these rich soils, and the phenomenon accelerated at a surprising rate during the drought period in the 1930s. Dust clouds blackened the sky to as far east as the Atlantic coast. These dust bowls were disastrous and continued until the late 1940s, with a heavy social impact. In parallel, in the most humid eastern areas, large-scale water erosion also occurred as a result of excessive tillage. The United States Department of Agriculture (USDA, and especially the soil scientist H.H. Bennett) then founded the famous Soil Conservation Service. In the Corn Belt and eastern Appalachian states, a large-scale programme was thus set up to implement erosion control measures involving embankments, cropping in alternate strips along contour lines. Later mulch tillage and direct seeding techniques were implemented. Questions were also raised as to whether or not tillage was actually necessary, but no immediate measures were taken. Although very costly, soil protection and restoration measures were actually easier to implement and more visible to the public eye than other agronomic solutions.

The suitability of tillage began being questioned in the 1930s, especially in regions where dry farming prevailed. Farmers, scientists (from the Universities of Nebraska, Kansas, Oklahoma and Texas) and USDA then initiated a programme to promote stubble mulch farming (currently mulch tillage), i.e. the use of crop residue to protect the soil during fallows. The same initiatives were taken in the Canadian prairie grain fields of Alberta. Superficial (10 cm) cutting tools (blades, sweeps, rod-weeders, etc.) were thus invented to cut weed roots without substantially disturbing the mulch layer, which very effectively protected the ground during the summer fallows. This was major progress, even revolutionary on the Great Plains, and was followed by chemical fallows in the 1950s, and direct seeding in the late 1960s.

Cattle herded back to the village. Common grazing on crop residue. Soil compaction and denudation occurs as a result of livestock trampling. Northern Cameroon.
© K. Naudin

Glossary

Alterite water table: Free water contained in the large open pores of thick water-saturated alteration materials in inter-tropical regions, which can range from 5 to 30 m deep over a sound substrate. This water table fluctuates markedly throughout the year (around 5-15 m). These water resources are tapped by villagers through wells to fulfil most of their water needs.

Capillary fringe: Zone of upward water flow via capillary action above the water table.

Dry farming: Highly mechanized agriculture in semiarid continental or Mediterranean environments (300-550 mm annual rainfall). This generally involves cereal cropping, every other year, alternating with a bare fallow, tilled with superficial machinery to control weeds and promote water storage for subsequent crops. Dry farming was (and still is to some degree) practiced in the Great Plains region of USA, on the Canadian prairies and in parts of Australia with a Mediterranean environment. The highly negative impacts of these practices include wind and/or water erosion because the ground remains bare for 18-21 consecutive months.

Feedback loop: When a process "feeds back" on its cause, thus enhancing this effect (positive feedback) or regulating it (negative feedback).

Glacis: Slightly sloping plain (grade of less than a few degrees) that is somewhat concave, rising upstream where it connects with the piedmonts of the dominant landforms.

Kaolinite: Type of nonexpansive clay (no gross fissured structure) typical of well-drained, but poor, relatively acidic and fragile structured soils of inter-tropical regions.

Leaching: Slow water percolation through the soil, accompanied by dissolution of solid materials within the soil.

Perched water table: Small episodic water table located in the superficial soil layers (e.g. a planosol or tropical ferruginous soil). It is located in porous material with an underlying clay horizon. It is supplied by rainfall that cannot percolate to the deep horizons. This is also called hypodermic runoff or flow.

Planosol: A soil characterized by the presence of a sudden discontinuity at less than 50 cm depth, and not resulting of mechanical overlap of two materials. The surface horizon (20-50 cm thick) is often discoloured (light grey), more massive and sandy than the more clayey underlying material.

Plinthite: In inter-tropical soils, this is mottled kaolinic clay (beige, grey, rusty, red), which corresponds to the fluctuation fringe of the alterite water table. The mottled colour is due to the presence of iron oxide particles in the clays. When episodically impregnated by the water table, the loose plinthite can harden and form a cap or hardpan, thus creating what was formerly called "laterite".

Runoff: Flow of rainwater along the soil surface.

Sealing: Destruction, via rainwater (storms), of the surface structure of the soil, which causes the formation of a continuous shiny, fine-textured coating when saturated with water.

Sheet erosion: A type of erosion that involves regular superficial removal of very fine soil particles due to moderate diffuse runoff.

Soil structure: The way the solid, mineral and/or organic, soil components (aggregated or not) are assembled. A structure is "good" when there is suitable soil aeration, water percolation and root development.

Tropical ferruginous soil: Soil that occurs throughout Sahelian and Sudanian Africa. It is grey, beige or reddish in colour, sandier at the surface than in the deeper layers, generally massive, compact and not very porous below 30 cm depth. It connects with a mottled clay zone below 1 m depth, where fluctuation of the alterite water table may occur.

Vertisol: A very clayey dark-grey to olive coloured soil formed by expansive montmorillonite clays. They swell and close up in the rainy season, while they shrink markedly (large cracks) in the the dry season. These soils are found in low areas (lowlands, plains, piedmonts) and on so-called "basic" rock (dark coloured).

DMC: an alternative to conventional cropping systems in desertification-stricken countries


1

Water is a scarce and uncertain resource in areas affected by desertification, but a large quantity is lost or unusable, i.e. it runs off on the surface and cannot be reached by crop plant roots in the deep horizons. This leads to the following contradiction in areas where desertification is under way: there is not sufficient water in some places (cropping areas) through which it transits and just remains for a very short amount of time, whereas excessive volumes of water may suddenly hit other places (channels and lower parts of glacis) within the same area and remain there for a long time. In both of these settings, cultivated ecosystems are disadvantaged and limited, or even condemned, by the unfavourable water and hydrological regimes.

Alternative cropping practices needed

Extreme climatic events are common in desertification-prone areas. Agricultural management schemes designed to buffer such harsh conditions are especially necessary. Do small farming families have any soil and crop management alternatives that would enable them to survive under or bypass such unfavourable conditions? Suitable alternative cropping practices should meet the following objectives:

- Attenuate erosion and reduce runoff to promote infiltration by creating favourable soil surface conditions;
- Facilitate access of plant root systems to deep moisture;
- Cushion the effects of climatic hazards during cropping seasons and between years;
- Enhance the resilience of new cropping systems to offset climatic hazards;
- Have socioeconomic impacts that will benefit farmers in the short-to-medium term, and the whole community within the local region, thus providing them with an incentive to adopt the alternative cropping practices.

These objectives can be fulfilled in cropping areas by applying the following principles:

- Establishing a permanent mulch cover to protect the soil (to control erosion, runoff, evaporation, high temperatures, etc.), thus preserving the moisture content and offsetting climatic hazards. This cover —via mineralization and humification (forming a humus layer)—**recycles minerals** and boosts soil carbon stocks, therefore improving the soil structure.
- Not tilling the soil so as to enable it to restructure itself via biomass input and to slow down the rate of humified organic matter mineralization.
- Decompacting clogged soil layers (20-40 to 80-100 cm depth) by, for instance, growing cover plants with strong root systems, especially grasses (*Brachiaria* sp., *Eleusine coracana*, sorghum, etc.)

2

1. Upland rice cropped on live Arachis pintoi *cover.*
Cerrados. *Brazil.*
2. Cotton cropped on sorghum mulch.
Cerrados. *Brazil.*
© L. Séguy

and leguminous plants (*Crotalaria* sp., *Cajanus cajan*), thus preparing fields for subsequent crops ("biological tillage").
- Promoting root uptake of moisture from deep horizons, therefore enhancing the water balance and helping to offset the irregular rainfall conditions.
- Improving livestock nutrition by combining crop and livestock farming through the use of cover plants as forage.

Direct seeding mulch-based cropping systems (DMC) can be adopted to meet these objectives, while making certain adjustments to address various ecological and agro-socioeconomic constraints.

Irrigation is essential when rainfall levels are less than 300 mm, and of course DMCs can also be implemented under these conditions.

Focus

DMC and conservation agriculture

DMCs are classified under "agroecological" approaches, and under what is now (since 2000) categorized as "conservation agriculture", which primarily implies no tillage, permanent vegetation cover and crop rotations.

Cropping systems that integrate environmental conservation and agricultural production

Since 1985, the French Agricultural Research Centre for International Development (CIRAD) has been developing and disseminating new cropping systems to smallholders in intertropical areas (including semiarid to subhumid areas)—they are based on two key field principles:
• Elimination of tillage (thus the name "no-till farming")
• Establishment of permanent vegetation cover

These systems boost the attractiveness, profitability, sustainability and environment-friendliness of agriculture. They emulate the functioning of forest ecosystems (which are nurtured by continuously recycling the mineral-rich biomass, without leakage on the surface or in the deep soil horizons), while also increasing crop production. In these systems, the soil is never tilled and **dead** or **live plant cover** is constantly maintained. The biomass that serves as mulch is residue from crops, interplanted crops or **relay crops,** legumes or grasses, which are used as **"nutrient pumps"** and make effective use of available water resources.

These plants have deep strong roots and can recycle nutrients from the deep soil horizons to the surface to be subsequently utilized by the main crops. They also produce substantial biomass and can grow under harsh or marginal conditions, during part of the dry season, in compacted soils and can ultimately be used as fodder for livestock.

The cover can be dried (via cutting, rolling or herbicide treatment, depending on the species and available resources), or left alive but controlled with low-dose applications of herbicides. The biomass is left lying on the soil surface, not buried and not burnt. Crops are sown directly in holes or furrows in the mulch layer. A broad range of seed drills have been tested: motorized seeders for large-scale farms, animal-drawn seeders (developed in southern Brazil), seeding wheels and manual cane planters.

Farmers with few resources may also simply use a planting stick or spade. First of all, this type of agriculture addresses the question that poor farmers may ask: what can we do without anything? It is also suitable for all types of equipment and intensification levels.

Roller-cutter (rolo-faca) *to flatten and kill the plant cover prior to sowing. Parana, Brazil.*
© M. Raunet

Glossary

Dead plant cover: Dead plant debris of all sorts that covers and protects the soil, anchored (via roots) or not, including crop residue, standing stubble, knocked down cover plants (cut, rolled or herbicide treated), vegetation imported from other sites, etc.

Live plant cover: Plants that provide soil cover and grow at the same time as the main crop during at least part of its cycle and potentially removed from the field after harvest for use (or not) as fodder.

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.

Nutrient pump: See mineral recycling.

Relay crop: Short-cycle crop grown between two main crops.

Brief historical review: no-till farming to DMC

The no-till farming concept was first developed and implemented in the field (90 million ha worldwide in 2005) in non-tropical areas—first in the United States as of the 1960s, then in subtropical southern Brazil, Australia, Argentina and Canada as of the 1970s. In these areas, many of which are under semiarid temperate or Mediterranean climates, groups of pioneering farmers who were aware that their lands were permanently degraded by erosion decided, along with the public and private research sector, to develop new innovative agricultural production strategies.

This movement has been continuously expanding in these countries (25 million ha in USA, 24 million ha in Brazil, 10 million ha in Australia and 12 million ha in Canada in 2005), through the development of new tools (especially specific seeding implements) and constant technical progress. However, until the early 1980s, little research had been conducted on this topic in tropical areas, where soils are more fragile and climatic conditions are harsher. As of 1983, first in large-scale mechanized farms in the Brazilian *cerrados* region (humid savannas), and then on smallholdings in partner countries of the South, CIRAD (coordinated by Lucien Séguy) succeeded in adapting and implementing the DMC concept on a large scale. This represented a remarkable change in strategy in tropical regions, and a major challenge because of the soil-climate conditions and rapid mineralization of organic matter.

CIRAD is now largely responsible for the incredible expansion of DMCs in the *cerrados*, with almost 10 million ha under this system in 2005 (as compared to 20,000 ha in 1992). This is clear evidence that these systems are very attractive from an economic standpoint. It has now been demonstrated, with matching results obtained in the field, that DMC is applicable in intertropical regions thanks to these new technologies and specific tropical agronomic methods (but the scope of possibilities has yet to be extensively explored)—to produce better, more sustainably and cost-effectively, while eliminating erosion and improving the soil quality. CIRAD and partners have developed these technologies through adaptive research strategies based on key agroecological principles without tillage, and oriented towards poor small-scale agriculture, or conditions requiring various levels of intensification, in all ecological conditions that occur in hot areas throughout the world (Brazil, Madagascar, Réunion, Côte d'Ivoire, Mali, Cameroon, Gabon, Mexico, Vietnam, Laos, Tunisia, etc.).

The specific features of DMCs will obviously differ under different conditions, depending on the human, economic and physical setting that prevails. Adaptive research must therefore be geared towards developing suitable cropping systems with the participation of local farmers.

Distribution of large areas (ha) under DMC worldwide (2005)
Source: World Congress on Conservation Agriculture (Nairobi, 2005)

DMC benefits for farmers

1

DMCs can benefit farmers in many ways (plot and farm levels) that can be measured in the short to medium term: agricultural, environmental and economic impacts.

Multiple agricultural benefits...

Permanent plant-based soil cover has different agricultural functions:

- Protection of the soil against water erosion through the creation of a barrier to offset the force of rain drops hitting the soil.
- Increased infiltration by not tilling the soil. Note that ploughing causes the formation of a "tillage pan" that hampers root growth and water percolation. Moreover, the action of roots and **bioactivity** in the soil improve the physical properties of cropped soil (especially porosity) and thus water infiltration.
- Reduction of evaporation by plant cover and mulch, thus reducing capillary upwelling.
- Reduction of soil temperature variations: plant cover buffers thermal extremes.
- Utilization of deep humidity: roots of the "crop plant-vegetation cover" unit gain access to deeper water reserves because of the enhanced physical properties of the soil.
- Creation of an environment that improves bioactivity: input of supplementary biomass to serve as a nutritional substrate, physical and water improvement of the soil and thermal buffering are favourable to the activity of bacteria, fungi and fauna (earthworms, ants, arthropods, collembola, insect larva, etc.).
- Weed control: the vegetation cover stalls weed germination via canopy shade and often its allelopathic properties (antagonistic biochemical secretions).
- Increased organic matter content in the soil (basis of soil fertility): biomass input (above- and below-ground) enables sustainable carbon fixation in the soil by humification, thus indirectly contributing to controlling the greenhouse effect.
- Enhancement of crop plant nutrition: slow mineralization of fresh biomass throughout the year by upwelling of minerals from deep horizons (**recycling**) continuously nourishes crops and reduces the need for supplementary fertilizer applications.
- Enhancement of livestock nutrition: the vegetation cover can often be grazed by livestock in the between-crop interval.

Cover plants are partially chosen for their strong root systems that "shatter" the soil and trigger bioactivity. This improves the efficacy of water and nutrient use, and thus harvest volumes and regularity.

Some efficient cover plants include grasses (genera *Brachiaria*, *Chloris*, *Panicum*, *Sorghum*, etc.) and leguminous plants (genera *Macroptilium*, *Stylosanthes*, *Mucuna*, *Crotolaria*, *Cajanus*, etc.). However, cover plants can potentially be degraded by fires, grazing herds, and sometimes termites (in Africa).

These drawbacks can be overcome by changing scale, from the farm to the agrarian region, with collective farms involving rational resource use,

2

1. Roots of cotton plants in soil compacted to 20 cm depth
Cerrados, *Brazil. CIRAD/Maeda Group partnership*
2. Roots of a cotton plant in non-compacted soil
Cerrados, *Brazil. CIRAD/Maeda Group partnership.*
© L. Séguy

contractualization between the different stakeholders (especially farmers and herders) to benefit everyone. Cover plants associated with quickset hedges could, for instance, improve herd management and reduce the risk of herds grazing and trampling the crops.

…and major environmental advantages

This agroecological agriculture offers solutions to the main short-term environmental challenges facing the world, especially in sub-arid to sub-humid areas threatened by desertification, through:

- erosion control, soil protection and cost-effective fertility regeneration;
- the reduction of shifting agriculture and thus deforestation;
- the reduction in water consumption for crop production and for rainfed crops that can consequently be grown in marginal areas;
- the high fertilizer application and pesticide treatment efficacy, thus reducing their pollution impact and improving food quality and security;
- the buffering of the effects of water flows and the reduction in flooding risks;
- the recovery of marginal soils abandoned because of their very low natural fertility.

Some of these environmental benefits of DMCs have been observed and assessed, while others are expected. In small-scale intertropical farming conditions, these technologies are recent and still mostly in the experimental phase. Moreover, we still do not have sufficient experience on a large scale (e.g. in an entire local region).

And also substantial economic benefits for farmers!

DMCs are especially attractive to farmers from an economic standpoint because of the very short-term potential advantages (e.g. the reduction of work time and laboriousness) along with more long-term benefits (e.g. stabilization of crop yields). DMCs are accessible to different categories of farmers, especially the poorest, because they can be adapted to a broad range of different agroecological conditions, production methods, and different levels of intensification.

Moreover, DMCs provide a valid and widely adoptable way to boost agricultural sustainability that is compatible with organic farming (no chemical inputs). An analysis of the economic advantages of DMCs should take many factors into account on farmer, village community, country and global environment levels.

For farmers, it is essential to determine:

- What can be directly measured: the costs for purchasing special equipment, seed and herbicides, etc., and the benefits such as the reduction in work time, input savings (fertilizer, pesticides, fuel) as compared to conventional agriculture, as well as increases in crop yields after 2-3 years.
- What can be indirectly measured: elimination of erosion, buffering of harsh fluctuating climatic conditions, enhancement of soil fertility, and better interaction with livestock farming.

Very few survey results are currently available to assess the direct and indirect economic benefits and costs. However, quantitative data are available from DMC experiments and practical implementations in different developing countries such as Cameroon (cf. page 30) and Tunisia.

Focus

DMC, soil fertility and biodiversity

The biodiversity of soils managed under DMC is associated with its fertility. In fact, these two factors are mutually stimulated in a positive feedback loop. As soon as the soil is no longer tilled and is permanently protected from erosion and harsh climatic conditions (hard rains, evaporation, excessive temperatures, etc.), and it is no longer stressed by pesticide treatments, it becomes a living agroecosystem, a veritable bioreactor, with a high level of bacteria, fungi, arthropods, earthworms, larvae and pollinising insects, etc. The interaction of these “soil engineers” enhances the soil structure and aeration, humifies and recycles the organic matter, boosts nitrogen fixation, phosphorus mineralization, thus boosting the resilience of the system and consequently agricultural sustainability.

Bioactivity in soil under DMC. Earthworm castings. Northern Cameroon.
© L. Séguy

A fertile soil is a living biologically rich soil. The notions of fertility, sustainability resilience and biodiversity in such soils are tightly linked. Conversely, a degraded soil is in the process of becoming biologically dead. Many conditions reduce the activity and biodiversity of a soil, including: mechanical disturbances (e.g. tillage), poor aeration, compaction (agricultural machinery, overgrazing, etc.), waterlogging, erosion and a shortage of fresh organic matter (to nourish bio-organisms), fires, sharp thermal contrasts, an excess of pesticides, a lack of humidity and excessive pH levels (less than 4 and above 9.5). When well managed, DMCs are geared towards (in addition to economic objectives of course) avoiding these unfavourable conditions as much as possible.

Root systems (crop, cover, and weed plants) contribute to this intrinsic biodiversity. These plants differ from season to season and nurture the soil through their mechanical and chemical actions (root secretions, decomposition/mineralization), thus benefiting the microflora and mesomacrofauna. In addition to preserving soil humidity and bioactivity, this bioactivity creates a favourable physicochemical environment, enhances mineral assimilation and creates a high volume of looser more aerated soil to be utilized by roots. This microflora and fauna facilitate constant recycling of minerals from leaf litter and dead roots, with minimum loss on the surface and in the deep horizons. In the soil, DMC and biodiversity thus closely interact and are jointly essential.

Example

Comparison of production costs in conventional cropping systems and under DMC in northern Tunisia

Fields managed conventionally were compared with fields under DMC on two reference farms located in the northern zone (500-700 mm rainfall/year) and in the southern zone (300-500 mm rainfall/year), with cereal and legume crops grown on both farms. The input cost was evaluated on the basis of market prices, while tillage costs were assessed according to labour fees. Mechanization costs (excluding tillage) were evaluated like the tillage costs, or directly (cost of equipment per hectare according to the life expectancy and the usage rate) or on the basis of the direct equipment costs. The results were as follows:

- On the northern farm, durum wheat crop production costs were 311 DT*/ha under DMC as compared to 353 under conventional agriculture, so DMC performed 12% better;
- On the southern farm, durum wheat crop production costs were 299 DT*/ha under DMC as compared to 309 under conventional agriculture, so DMC performed 3% better;
- On the southern farm, DMC again performed 3% better with respect to pea crop production costs.

These direct data are still not very convincing, but it is especially important to add the range of other benefits of DMC: lower seed drill depreciation expenses, sales of fodder or silage derived from cover plants, cover plants grazed by farm livestock herds (savings on livestock feed and/or fodder crops, improved herd performance), conservation of biomass, which is returned to the soil, thus increasing its fertility.

1. Wheat sown on cereal crop residue. Tunisia.
2. Wheat sown on cereal mulch (left, after sowing with a direct seeding drill; far left, conventional agriculture with tillage). Tunisia.

DMCs enable Tunisian farmers to reduce production costs (reduced diesel fuel consumption by an estimated 50-80 l/ha, or 20-30 DT*/ha, and lower expenses for equipment and spare parts), to reduce climatic hazards through the "buffering" effect of DMCs, restoration of soils and their organic matter content, general enhancement of the cropping system (especially through better integration of livestock production), and increased potential for growing crops on slopes and in so-called idle soils.

From Chouen *et al.*, 2004

* 1 euro=1,7171 Tunisian dinars (DT), March 2007

Glossary

Bioactivity: Effects, products and transformations resulting from the activities of living organisms (micro-organisms, plants, animals, etc.) in a given nutrient- and energy-deficient environment.

Mineral recycling: Biological upwelling (through roots and surface biomass) and reuse of soil minerals that would otherwise be lost via runoff or leaching.

Cumulative effects and services of DMCs for landscapes and communities

Considering their recent development, DMCs have yet to be adopted by all smallholders within a catchment basin in developing countries—this would however be necessary to be able to assess the impacts and **externalities** of these systems on a real scale. This chapter just covers processes that could be expected during such changes of scale. Cumulative and interactive effects (positive externalities) could be expected on local regional, catchment and landscape scales once DMC practices are widely adopted. Some functions and services handed over to local communities have monetary and social values that should be evaluated by environmental economists.

Drawing water from a well. Mauritania.
© M. Raunet

Important indirect agro-environmental effects

The beneficial effects of improved soil water and crop management resulting from widespread use of DMCs would, among other factors, concern:

■ *Settling agriculture:* Shifting agriculture in semi-arid and sub-humid areas, with slashing-and-burning of the tree cover, can induce desertification when fallow periods are too short to enable reforestation and soil fertility restoration. Implementation of DMCs, which combine crop production and soil fertility restoration at the same site over the same period, would keep farmers from wandering and consequently reduce deforestation.

■ *Woody plant regeneration:* Cover plants used in DMCs also provide good fodder. Widespread adoption of DMCs would thus reduce stress on natural rangelands. In addition to settling agriculture, DMCs could promote settling of herders. Bush fires, which are traditionally ignited to regenerate rangelands, would also be less necessary, thus leaving woodlands and forests, along with associated fauna, time to regenerate.

■ *Stalling erosion:* Because of the permanent vegetation cover and absence of tillage, DMCs reduce, or even eliminate, erosion and runoff—key factors in desertification and soil degradation. Rainwater also percolates better through DMC-managed soils. One key expected impact thus concerns downstream reservoirs and dams which are consequently less affected by siltation of mud and sand. In the Mediterranean Basin (North Africa), large-scale expensive anti-erosion development projects, soil protection and restoration (DRS) projects, and water and soil conservation (WSC) projects, would thus likely no longer be necessary if catchments were generally managed under DMCs.

■ *Flood prevention:* For the above-mentioned reasons (low, slow, delayed and dispersed runoff in watersheds), the downstream parts of the landscape, depressions, basins, low ground areas and lower parts of glacis, would no longer be flooded. Local regions and inhabited areas, which generally have a high production potential for crops and grazings (vertisols, lowland hydromorphic soils, etc.) would be better protected and less often doomed by sudden water influxes.

■ *Rise in the water table:* The increased overall water infiltration in catchment basins has a very positive impact on water tables embedded in the thick regolith mantle underlying soils in intertropical regions, i.e. leading to a substantial rise (of one to several metres). The benefits are noted on several levels:

- Village wells are not as deep and are less conducive to drying up.
- The more regular flows of lowland hydrological regimes are beneficial for rice cropping, out-of-season vegetable cropping and livestock watering.
- The shallow water table could partially be tapped to feed “groundwater crops” such as rice and root and tuber crops (yam, cassava, sweet potato, etc.).

Low ground areas supplied with water from runoff and the rising water table. Fringe of palmyra palms with a shallow water table (western Madagascar).
© M. Raunet

- The fringes that vary in width (20-200 m) along the edge of low ground areas and depressions could also offset the irregular rainfall conditions to the benefit of tree crops in orchards.
- Stream flows would be more regular throughout the year.

■ *Carbon sequestration:* Biomass derived from DMC crops (cover plants and crop residue) and from the natural vegetation (expected woody plant regrowth) generally increase on a territorial scale. In semiarid to semi-humid savanna regions, DMC use and the elimination of bush fires would theoretically enable storage of at least 0.5-1.5 t/ha of carbon per year over 10 years in soils within agrarian territories. A high level of carbon sequestration could be expected throughout the area by combining DMCs, rangelands and regenerated forests. A theoretical schematic calculation indicates that a shift from a degraded regional environment (traditional crops, degraded soils and vegetation) to a "regenerated" regional environment (an equal share of DMC, regenerated forests and rangelands) would increase carbon contents by around 4.7 t/ha/year over 15 years.

Focus

DMC and agrobiodiversity

Herd grazing on Brachiaria *cover.*
Cerados. *Brazil.*
© L. Séguy

The gene pool of crop plants and their biodiversity are declining to a drastic extent as a result of the use of genetically modified organisms (GMOs) and the specialization and uniformization of intensive conventional agriculture in developed countries (and in some Asian countries where the Green Revolution is under way, e.g. in India and Pakistan). Many potentially useful and invaluable genes adapted to various environments are disappearing. This is a dramatic situation, especially at a time when global warming will cause substantial degradation of many environments to which humans will have to adapt. Maximum biodiversity is needed to be able to deal with this dilemma.

From a varietal standpoint, DMCs make it possible to effectively utilize "genotype x environment synergies". Many varieties that are considered to be susceptible to certain pests under intensive agriculture conditions are eliminated through breeding, despite other advantages they offer (hardiness, low fertilizer needs, etc.). These varieties are actually better adapted and therefore much better protected or tolerant under some microenvironmental conditions created by DMCs. Many varieties could thus be rehabilitated and genetically tapped in DMC, thus enhancing biodiversity. This also applies to the diversity of cover plants (legumes, grasses, crucifers, etc.), which are usually multifunctional (production of biomass, fodder, etc.). Farms managed under DMC—with low input levels, and which focus more on agronomic aspects and diversification than on chemical inputs and monocultures—are systems that utilize and create biodiversity, which is essential for enhancing agroecosystem resilience.

In and around roots, the diversity of crop species and cover species, between systems, promote the development of a high variety of microorganisms that help to nourish plants (symbiotic nitrogen-fixing bacteria, mycorrhiza, etc.). Schematically, DMCs function and improve in a virtuous circle: they create fertility, which creates biodiversity, which in turn creates more fertility.

Protected areas: contribution of DMCs to biodiversity conservation

DMCs can potentially have an indirect impact on wildlife biodiversity by being integrated in agricultural schemes along the periphery of protected areas that host large animals. These areas are “porous” for wildlife and agriculture (usually slash-and-burn farming). This cohabitation is usually conflictual—large animals destroy crops, thus prompting farmers to kill them and, conversely, agriculture destroys the environment and wildlife habitats (not to mention poaching).

This situation could worsen with climate warming and the concomitant negative impact on biodiversity. Such situations are very common in Africa, where protected and peripheral areas are often threatened by human activities. This is the case, for instance, in areas classified of biological interest by the World Wide Fund for Nature (WWF). These are not officially protected areas but they still host a quarter of the large wildlife species that symbolize Africa (elephants, white rhinoceros, giraffes, etc.). In southern Africa, considering the high human pressure on the land, WWF has understood that settling and the sustainability of agriculture in these regions are essential for preserving wildlife.

The Miombo woodland regions (typical of woodlands in southern Africa) are considered marginal because of the poor soil quality, low rainfall and the lack of interest of local authorities, development and funding agencies. In these areas, the challenge is to integrate agriculture on vegetation cover (often fodder), herding with controlled bush burning and wildlife management.

Giraffes in Niger.
M.L. Sabrié ©IRD

This major challenge especially concerns all southern African regions hosting large animals (from Angola to Mozambique, from Tanzania to South Africa, through Zimbabwe, Malawi, Zambia and Botswana).

DMCs help to settle agricultural land since bush fallows are no longer necessary for restoring soil fertility. They can therefore help in overcoming conflicts between proponents of biodiversity conservation and agricultural production.

Technicians of SODECOTON monitoring an experimental field cropped with maize/mucuna. Northern Cameroon.
© K. Naudin

Indirect economic benefits of DMCs

■ *On local area (“terroir”), regional and country levels,* the benefits are positive externalities (not directly levied by farmers) such as enhanced protection of catchments and downstream works (dams, roads, bridges, houses, etc.). These externalities are hard to evaluate from an economic standpoint, since the benefits generally have no market value. The costs for communities (or to share with farmers) are expenditures for training, awareness campaigns, coordination and extension, even external technical assistance if required, follow-up research and for improving services in rural areas (credit, markets, supply systems, etc.).

■ *On a global level,* DMCs help to curb the greenhouse effect by increasing the carbon sequestering capacity of the soil, enhancing biodiversity (fauna and flora, gene reserves, landscapes) and economic activities.

Runoff after heavy rainfall.
Béja, Tunisia.
© J.-F. Richard

Methods for assessing current externalities

Externalities should be assessed to determine the total economic benefits of DMCs. The French Development Agency (AFD) proposed a method in 2003 based on previous studies, especially those of Paggiola *et al.* (2005) and Pimentel *et al.* (1995). The different expected positive externalities associated with widespread implementation of DMCs and which could be estimated on a macroeconomic scale are as follows:

- *Reduction of the impact of runoff and erosion:* damage associated with rising waters and flooding, disturbance of aquatic ecosystems, disturbance of navigability, the need for supplementary water treatment due to sedimentation, loss of tourism and recreational interest.
- *Reduction of the impact on water reservoirs* (small catchment ponds, small and large dams).

Methods for estimating these impacts involve contingent assessments, transportation cost evaluations, measurement of supplementary protection costs associated with sedimentation, measurement of direct costs of flooding (destruction, habitat impacts, land sterilization, etc.), measurement of the loss of dam capacities and the resulting impact on irrigation and hydroelectricity generation. The simplest method is to use the following multiplication formula: "the cost of theoretical dredging of a square metre of sediment x the quantity of sediment avoided in DMC".

Example

Economic benefits from carbon storage: a case study in Tunisia

A quick calculation gives the following results: DMCs enable storage of 0.5 tonnes of carbon per hectare over a 20 year period. If 60% of the fertile land in Tunisia is cropped under DMC (3 million ha), and if the cost of international damages per tonne of emitted carbon is estimated at USD20, then the adoption of DMC in Tunisia would represent an international non-updated profit of USD600 million over 20 years (10 x 3 x 10^6 x 20 years).

Considering that DMC adoption leads to a 40% reduction in agricultural carbon emissions, and assuming that this represents 40% of the carbon emissions in Tunisia, and knowing that this country emitted 2.6 t of CO_2 per capita per year in 1994 (around 10 million inhabitants), the total international profit would be USD21 million in 2003. Without updating, this represents USD462 million over 20 years!

From Richard, 2004.

Flood in a field after a storm. Mali. © M. Raunet

Other externalities could also be assessed, such as:

■ *Reduction of surface and groundwater borne input pollution:* note that DMCs ultimately enable farmers to reduce pesticide use through better pest control by cover vegetation and integrated control. Methods used to assess this impact involve evaluating fertilizer and pesticide transfers from the field into the water column, the impact of DMCs on input quantities used, and the economic cost of the pollution caused. It is essential to rigorously measure all fertilizer and pesticide quantities used, along with all resulting pollution, both locally and elsewhere, while pricing the economic damage caused by this pollution. To further complicate this operation, there are many other hard to measure impacts due to input use (ecological, socio-cultural, recreational, and direct economic damage). The cost of treatment avoided by the implementation of DMCs could nevertheless be calculated by the following multiplication formula: "unit cost x avoided quantity of each pollutant", while adding an estimate of the associated health impacts.

■ *Water table recharge and the regulation of stream water flow induced by DMC use are hard to evaluate.* Indeed, how can the value of this water that becomes available through DMC use be determined? Perhaps by taking the water **opportunity cost** into account, i.e. evaluating quantities stored in the rainy season due to DMC use, and subsequently available for human and agricultural use in the dry season.

Focus

Two methods for economic assessment of environmental assets

■ *The transport cost assessment method* (or transportation cost) is an indirect way of economically assessing an environmental asset. An economic stakeholder may need to consume marketable goods when using an environmental asset. The value of this asset could thus be determined on the basis of this measurable consumption. For instance, a stakeholder will consume petrol to reach a distant forest to be monitored, so this fuel cost is thus recorded.

■ *The contingent assessment method* is a direct way of economically assessing an environmental asset. It involves conducting surveys of economic stakeholders to determine the price (or expenditure) they are ready to pay to improve and benefit from the quality of a service provided by an environmental asset or to rectify a quality degradation of this asset.

■ *Reduction of damage to downstream infrastructures* (drainage networks, bridges, roads) through widespread adoption of DMCs is also hard to quantify. Some monetary assessment methods are still possible, e.g. the risk of a road outage occurring can by assessed by the following multiplication formula: "total cost of an outage x lower probability of this occurring because of DMC use". Moreover, DMC use leads to savings on construction and maintenance costs concerning drainage networks and structures. The reduction in runoff due to DMC use leads to a reduction in the number of structures necessary and in their size. Infrastructure maintenance savings expected with widespread adoption of DMCs can be calculated on the basis of unit maintenance costs incurred by a certain quantity of water and eroded land in the area.

■ *Biodiversity and the natural environment:* It is essential to distinguish between the biodiversity in the soil, that in the "replacement soil", and that in aquatic systems:

- Soil biodiversity is promoted by not tilling the soil, a key agronomic feature of DMC (increasing the number of species and of individuals per species). The reduction in pesticide and herbicide use ultimately expected with DMC adoption also has a positive impact on biodiversity enhancement.
- Biodiversity of "replacement soil": farmers may clear new land in forested areas when their fields are too degraded **(slash-and-burn agriculture)**. Indirectly, DMC use tends to induce farmers to settle since this cropping system substantially improves soil fertility. This in turn helps to stall deforestation, thus contributing to biodiversity preservation.
- Aquatic systems are degraded by inputs and sedimentation. DMC use should help to preserve aquatic biodiversity by reducing the volume of waterborne inputs and sedimentation.

Biodiversity can be considered in terms of three values: a usage (or functional) value, an esthetic value, and a sociocultural value. The usage value can be estimated by measuring the biological quality of the soil and aquatic systems (including fish resources and market prices). The esthetic value can be assessed through impact studies on the loss of tourism and recreational interest of sites on the basis of a contingent assessment or the transportation cost assessment method. By this latter method, however, the "consent to pay" is hard to measure in developing countries. The sociocultural value can be estimated through a contingent assessment. Quantitative data, especially from fauna and flora inventories, are required to carry out all of these assessments, but unfortunately such data are seldom available for areas affected by desertification.

Example

Economic benefits and DMCs: a case study in Tunisia

For the community, DMC adoption is expected to lead to an increase in agricultural added value, as well as a reduction in petroleum fuel consumption (due to the elimination of tillage) and in expenditures for equipment and spare parts. In the longer term, widespread adoption of DMCs could lead to a reduction in costly conventional anti-erosion water and soil conservation practices (estimated at 400 DT/ha*). The water table recharge and reduction in mud silting of dams and risks to infrastructures are also potentially beneficial for the community.

DMC implementation has four effects on field carbon levels: elimination of carbon release generally triggered by tillage, reduction of emissions associated with fuel consumption, increased carbon storage due to the higher organic matter content in the soil, and better carbon sequestration in the soil due to a reduction in surface erosion. With a tonne of carbon estimated at USD10**, storage of 14 t/ha of carbon over 10 years by DMC adoption, a 200 ha farm would potentially achieve a profit of 28,000 DT*, i.e. the amount needed to purchase a specialized seed drill.

Expensive construction of soil protection and restoration bench terraces that are relatively inefficient and reduce the cropping area. Goubellat region. Tunisia.
© S. Chouen

From Chouen *et al.*, 2004.

* 1 euro=1,7171 Tunisian dinars (DT), March 2007
** As part of the market for carbon emission rights set out in the Kyoto Protocol.

Focus

What is the purpose of the Clean Development Mechanism?

The Clean Development Mechanism (CDM) is one of the financial instruments of the Kyoto Protocol of the United Nations Framework Convention on Climate Change. It offers developed countries, or economic stakeholders of such countries, the possibility of boosting their greenhouse gas emission quota by implementing emission reduction projects or carbon sequestration projects in developing countries.

■ *Carbon sequestration:* DMC projects are often integrated within climate change projects with a broader scope. DMC implementation can actually boost carbon storage. Moreover, the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) by the Conference of the Parties (COP7) expanded the notion of "carbon sinks" to cropping systems. Within the framework of the Clean Development Mechanism (CDM), "sink" projects can be launched and funded by developed countries to meet their own obligations, but the practical procedures have yet to be delineated. The mean relative carbon storage via DMCs ranges from 0.5 to 1.5 t/ha/year. Globally, DMCs could reduce agricultural carbon emissions by 40%. The economic impact then depends on the market price of carbon, but could be estimated at around USD10 per tonne. The World Bank has estimated the cost of international damage per tonne of carbon emitted at USD20*.

Several problems arise concerning monetary assessment of externalities: understanding the phenomena involved and taking them all into account, especially the **off-site effects,** the scarcity of available quantitative data, the difficulty in evaluating reference situations and the "initial state", the difficulty in generalizing experimental results *ad hoc* (it is essential to be able to verify the results statistically, which is not yet possible). Quantified estimates for each of these points are hard to sum up. For instance, in the Tunisian setting, the key benefits of DMCs include the reduction of erosion and runoff, thus reducing mud silting of dams (0.1% of the GDP according to a World Bank study), the reduction in stream sedimentation, and the hydrological impact (water table recharge, stream regulation). The potential carbon sequestration benefits were roughly estimated, but benefits concerning water quality and biodiversity are much harder to quantify.

* World Bank, 2003. Évaluation du coût de la dégradation de l'environnement en Tunisie. Washington.

A sheep herd grazing on durum wheat crop residue. Mateur, Tunisia.
© J.F. Richard

Glossary

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.

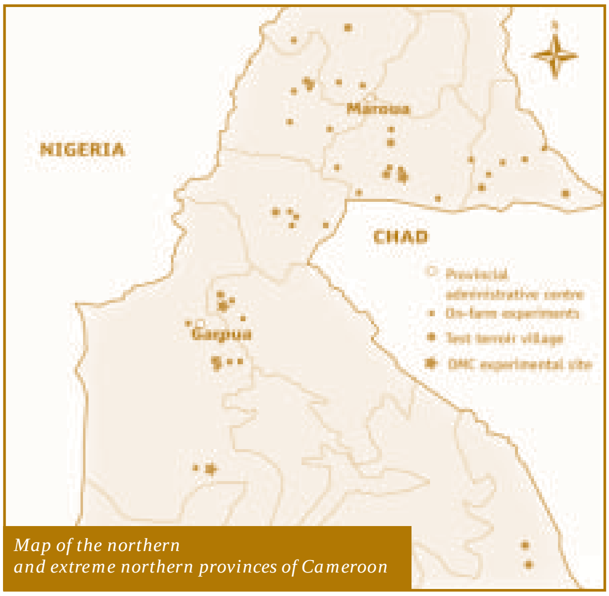
Off-site effects: These are effects noted remote from the sites where DMCs are actually being implemented, e.g. the reduced quantities of sediment transported by rivers outside of the catchment in which DMCs prevail—this is a positive off-site effect (or "positive externality").

Opportunity cost: This expresses what an economic stakeholder loses when making a choice, i.e. the value corresponding to the unchosen option.

Slash-and-burn 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.

Four years of participative experiments with farmers on DMC cotton crops in northern Cameroon

DMCs at SODECOTON (*Société de Développement du Coton* au Cameroun)



Map of the northern and extreme northern provinces of Cameroon

Since 1994, SODECOTON, through DPGT *(Développement Paysannal et Gestion de Terroir)* and ESA *(Eau-Sol-Arbre)* projects, has been increasing its use of soil fertility maintenance techniques in cotton-growing areas of northern Cameroon (Sudanian savanna region with annual rainfall ranging from 600 mm in the north to 1,200 mm in the south). This region is highly affected by severe erosion and land degradation. These techniques mainly involve anti-erosion structures (grassy strips, stone windrows, canal reaches, etc.), preservation of *Acacia albida* and promotion of organic manure. DMCs have been tested since 2001 as an alternative to these initiatives, with the 2001-2005 period serving as the technical development phase. More than 200 farmers have currently tested DMCs in their fields.

Development of cotton-cereal based DMCs

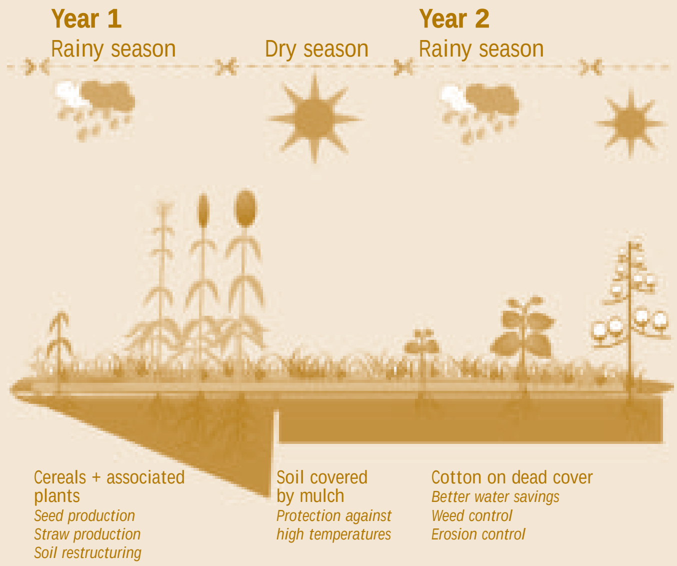
Farmers in northern Cameroon commonly use cotton-cereal rotations, so the first DMCs were based on this crop combination. In the first year, the cereal crop (sorghum/maize/millet) is intercropped with a cover plant *(Brachiaria ruziziensis, Mucuna pruriens, Dolichos lablab, Crotalaria retusa, Vigna unguiculata)*. Such associations enable farmers to increase biomass production by twofold in their fields. The biomass produced is left in the field or partially grazed by livestock. It then serves as mulch for the subsequent cotton crop the next year.

Focus

DMCs in northern Cameroon: how does it function?

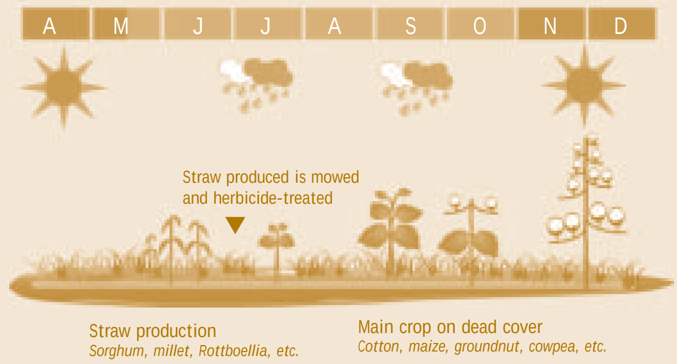
Two types of DMC are generally being tested in northern Cameroon:

■ Biomass production every other year



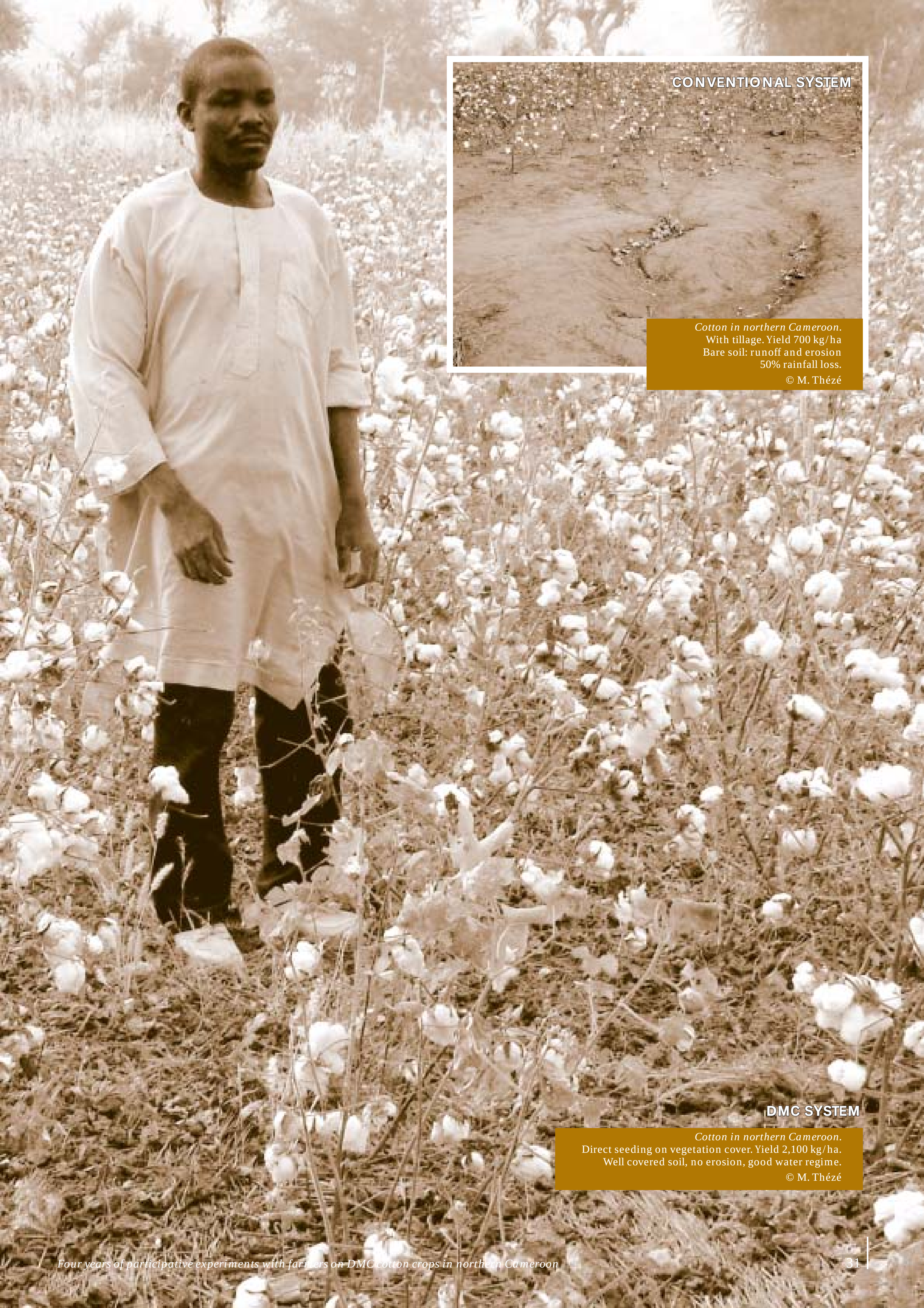
- **Advantages:** adapted to areas with low rainfall, corresponds to conventional cereal-cotton crop rotations.
- **Drawbacks:** the vegetation cover must be protected if grazed by livestock.

■ Biomass production during the same year as the main crop



- **Advantages:** the plot does not have to be protected between seasons
- **Drawbacks:** requires a 6-month rainy season and herbicide treatments.

From Séguy *et al.* modified.



CONVENTIONAL SYSTEM

Cotton in northern Cameroon.
With tillage. Yield 700 kg/ha
Bare soil: runoff and erosion
50% rainfall loss.
© M. Thézé

DMC SYSTEM

Cotton in northern Cameroon.
Direct seeding on vegetation cover. Yield 2,100 kg/ha.
Well covered soil, no erosion, good water regime.
© M. Thézé

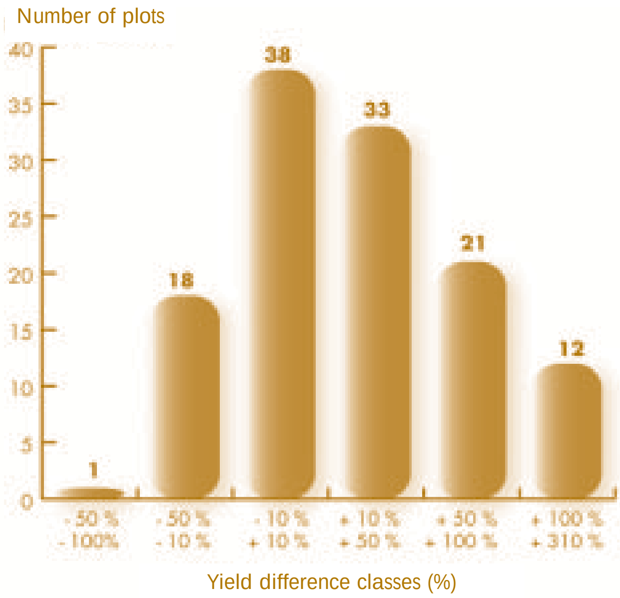
Farmer's field under DMC. Cotton cropped on mulch from the sorghum crop grown the previous year. Northern Cameroon

How are the trials conducted?

Farmers' fields are generally a quarter hectare in size. They divide their fields into two, three or four subplots and test DMC on one of them (200-1,250 m²), with the others cropped conventionally. All work is done by the farmers. The project provides advice when needed, along with herbicide spraying equipment with caches (for spot spraying).

Equivalent or slightly higher yields

From 2001 to 2005, in the extreme northern region of Cameroon, where the drought is most common and intense, DMC cotton plots produced around 1.4 t/ha, as compared to 1.16 t/ha in conventional plots (as measured in more than 130 plots during the 2001, 2002, 2003, 2004 and 2005 crop seasons). This yield gain was mainly due to better infiltration and reduced rainwater evaporation. Cotton fibre quality enhancement could be expected in addition to these quantitative gains.



Distribution of plots according to differences in sorghum yields between the DMC and control parts (%)

2001/2002/2003/2004 crop seasons, 123 plot pairs
10% + 50%: yields over 10-50% on the 33 DMC plots.

Comparison of cotton yields obtained under DMC and in the control (conventionally managed) plots
Means for the 2001 to 2005 crop seasons in the northern and extreme northern provinces
From Naudin & Balarabe, 2006.

	DMC		Control	
	Mean yield (kg/ha)	Number of plots	Mean yield (kg/ha)	Number of plots
Extreme North	1,421	139	1,164	134
North	1,689	66	1,510	66

Comparison of cotton yield components in fields under DMC and in the control (conventionally managed) plots.

2004 crop season, northern and extreme northern provinces, Cameroon
From Naudin & Balarabe, 2005b.

Province	System	Seed holes/ha	Plants/ seed hole	Bolls/ plant	Boll weight (g)	Yield (kg/ha)	N° sub-plots
Extreme North	Control	26,402	1.89	6.32	4.66	1,468	32
	DMC	2,455	1.83	6.58	5.37	1,776	34
North	Control	19,655	1.43	12.37	5.28	1,837	16
	DMC	21,176	1.48	12.22	5.20	1,988	15

Scarce rainfall percolates better through the soil

In conventional cropping systems in the extreme northern region, rainfall is very often a yield-limiting factor for cotton and other crops. Moreover, the scarce rainfall often does not percolate through the soil due to the soil's natural tendency to form a crust on the surface. This tendency may be worsened by conventional cropping techniques that leave the soil bare at the onset of the rainy season. Raindrops hitting the soil promotes crusting.

DMCs overcome this phenomenon due to the presence of mulch on the soil surface and the intense bioactivity in the soil, which in turn substantially enhances water infiltration. For instance, measurements were carried out in the experimental site at Zouana (extreme north) and in three neighbouring plots between 29 June and 2 September 2004 (397 mm total precipitation). In the conventionally managed plots (direct seeding without cover and with tillage), more than a quarter of the rainfall was carried away via runoff. This quantity was 10-fold lower in the DMC plots. Out of almost 400 mm of rainfall, 100 mm were thus lost with conventional cropping techniques, whereas almost all the rainwater that fell in the DMC plots infiltrated the soil.

Quantity of runoff water in three types of plot cropped since 2002

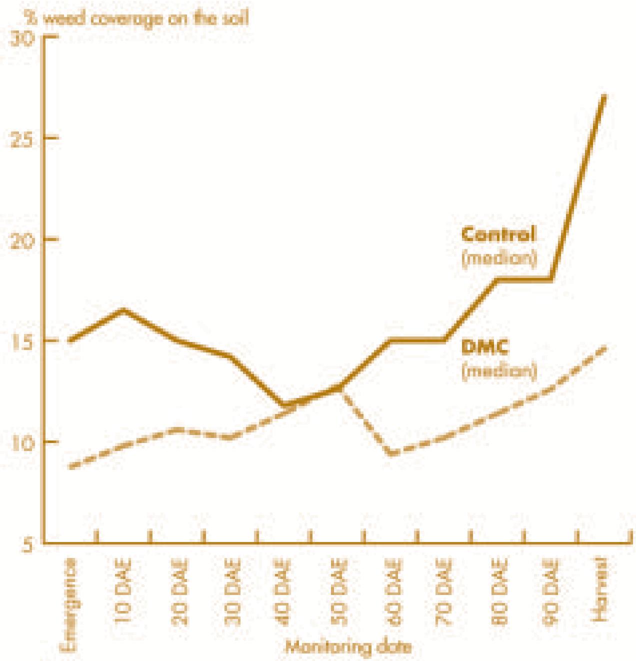
From Naudin *et al.*, 2005a.

Type of plot	Quantity of water lost (mm)
Tillage (no vegetation cover)	95*
Direct seeding only (without tillage or soil cover)	106*
DMC (without tillage and with vegetation cover)	10

* Quantity underestimated.

High agricultural and economic impacts

DMCs also have long-term effects such as improving the organic matter level, reducing erosion, enhancing soil fertility and reducing weed stress.



Weed infestation patterns from cotton emergence to harvest
Measured in 50 plots in the northern and extreme northern provinces, Cameroon
DAE: days after emergence
The median was calculated (not the mean)

From Naudin *et al.*, 2005a.

Cotton cropped on mulch (Brachiaria and sorghum, right) and without mulch (control, left). Soil moisture was better preserved in the part managed under DMC. Northern Cameroon.
© K. Naudin

Farmers also seek short- and medium-term economic benefits. There are significant differences between conventionally managed plots and DMC plots, e.g. less working time, lower production costs, etc.

Gains in DMC plots	Added costs
Reduction in working time due to the elimination of some tasks: • Ploughing • Ridging • Weeding (if there issufficient mulch)	• Herbicides for spot treatments (only if there is not sufficient mulch) • Urea (50 kg/ha) during the first 3 years if the mulch is composed of grasses (unnecessary if based on leguminous plants)

The overall results are generally in favour of DMCs, in terms of net income per hectare, number of working days per hectare, and productivity per working day.

Comparison of key economic indicators in fields under DMC and in the control (conventionally managed) plots
2004 crop season, northern and extreme northern provinces, Cameroon.

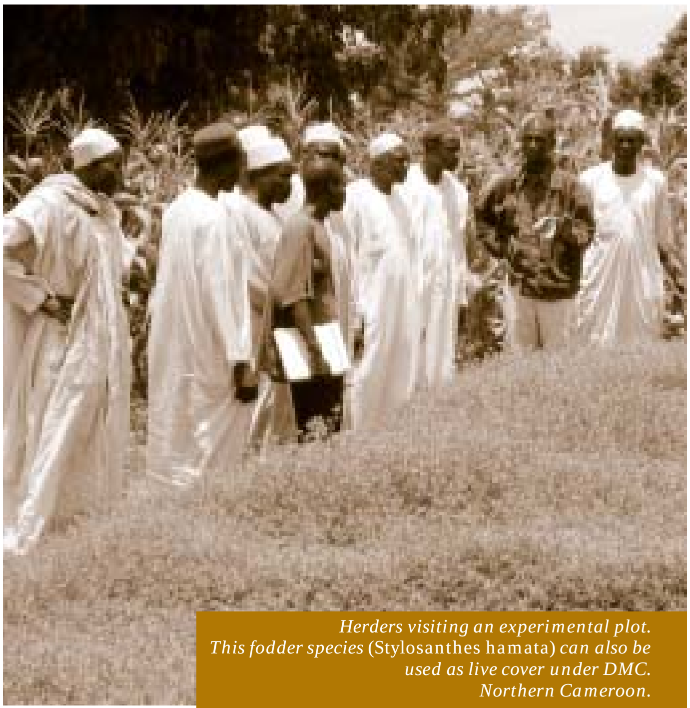
From Naudin & Balarabe, 2005b.

	DMC	Control	N° plot pairs
Net income/ha (euros)	301	225	41
Working days/ha (man-days)	101	109	28
Productivity per day worked by farmer or farmer's family (euros/working day)	3,53	2,28	22

An ongoing project

Conducting on-farm tests is very interesting because it enables researchers to quickly get farmers' opinion on the techniques being developed for extension. At the end of these 4 years of on-farm tests, the focus is now on dissemination and on the farm supervisory staff. From a research standpoint, the following topics have yet to be investigated in detail:

- fertilization tailored to the cover plants used in the rotation;
- herbicide treatments to reduce the workload in the most weed-infested plots (northern province) when the mulch layer is insufficient;
- biomass production the same year as the cotton crop by benefiting from the first rains of the season.



Herders visiting an experimental plot. This fodder species (Stylosanthes hamata) can also be used as live cover under DMC. Northern Cameroon.
© K. Naudin

Focus

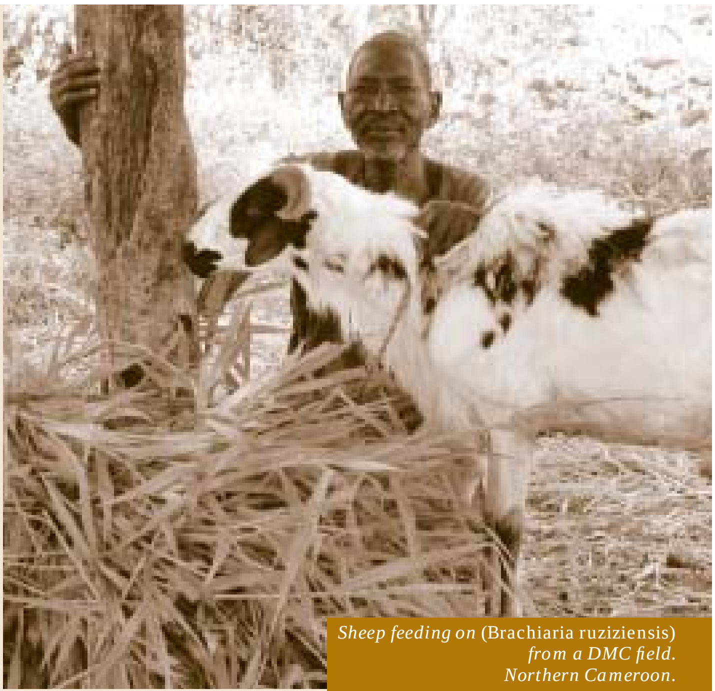
Agriculture, herding and DMC: it is sometimes hard to balance conflicting interests in Sudano-Sahelian regions of Africa

Agriculture and herding have long been described as the two mainstays of rural development, but they are often hard to integrate in many small-scale family farming situations in the South. Ethnic considerations (some ethnic groups practice farming and others herding) are tied in with competition for land or antagonistic management of available biomass (e.g. herders often ignite grass fires to promote regrowth while farmers try to preserve the vegetation). This situation can become conflictual when there is excessive pressure on available resources. When presenting DMCs at meetings in areas where both farming and herding are practiced, local people often point out that such systems could not be developed due to competition for biomass (cover plants) during the dry season. Why can't these two activities be complementary rather than conflictual?

In many situations, a farmer who manages to obtain a herder status achieves social advancement and is guaranteed a new source of more regular income. There is little chance that smallholders close to self-subsistency will decide to preserve cover vegetation within a DMC framework since everything that is grown on the farm must immediately generate income or food.

In this setting, it is possible to grow food crops or associations that will enable farmers to produce seed that will be exported from the field and biomass that will serve as cover. A range of interesting cover plants can be used under DMC which are able to produce biomass, grow under harsh conditions, smother weeds, etc., but they will not generate income or produce food for the farmer's family. It is essential to find ways to promote this biomass production, and livestock feed is often the best way:

- feeding one or several animals during the biomass growth phase;
- grazing or even overgrazing of a cover plant to weaken it before sowing the main crop;
- mowing and storage of part of the biomass as hay or silage and then selling or using it for livestock feed during the dry season.



Sheep feeding on (Brachiaria ruziziensis) *from a DMC field. Northern Cameroon.*
© K. Naudin

Farmers could profit from this biomass by, for example, selling it to periurban livestock farmers during the dry season, or using it to feed sheep before Muslim festivals. In some cases, this could turn out to be much more financially rewarding than marketing the seed produced, especially in areas like North Africa where straw often has more value than seed crops. In the region of Bobo Dioulasso, Burkina Faso, women's groups sell fresh silage for 70-100 CFA francs (0.1-0.15 euro) per kilogramme.

Interactions between agriculture and herding can be reconsidered through the use of cover plants in DMC, while also focusing on developing new systems. The rules and conditions for managing produced biomass must be determined, along with the share that can be used for livestock feed and the portion which should be left in the field to serve as cover (what plant, type of management, use and best combination with the main crop?). This is a major issue to be addressed by agronomy and livestock production researchers. DMCs could turn out to be suitable for integrating herding and crop farming and orienting the system towards useful biomass production, thus reducing competition between farmers and herders for biomass.

DMC: a promising approach for combating desertification?

Meeting of technicians and farmers involved in DMC (exchanging views on management strategies). Northern Cameroon.
© K. Naudin

Natural and human-induced processes underlie desertification. In the 21st century, climate change and population patterns will likely accelerate these mechanisms and broaden the range of areas affected by desertification, especially in Africa. Farmers in inter-tropical regions are going to have to adapt to these harsh conditions prompted by climatic variations, water stress and erosion phenomena. This will require new farming systems designed especially to enhance agroecosystem protection, production and resilience, i.e. resistance to both natural and human-induced stress.

Desertification affects vast areas and is one of the processes associated with global warming. Biodiversity preservation and/or enhancement is thus crucial to increase the resilience and thus the sustainability of agroecosystems, and consequently to facilitate their adaptation to continual change. These biodiversity initiatives should be focused on different scales, from soil microflora and fauna to forest ecosystem preservation. They should also promote inter- and intra-specific agrobiodiversity of agrarian systems: crop rotations and diversification, mixed covers of plants with different but complementary properties and functions, and utilization of a range of genetic resources, including traditional resources.

Direct seeding mulch-based cropping systems (DMC) meet all of these requirements, while also providing several other direct benefits for farmers (labour savings, improvement of soil fertility, etc.). In addition, these systems have many positive external effects (concerning water, biodiversity, economic factors, etc.), on different scales (farm, *"terroir"*, catchment basin, regional and national community, global), such as increased carbon sequestration, which means they also contribute to combating the greenhouse effect.

DMC systems are relatively easy to plan and implement, but are somewhat complex from a technical standpoint, so disseminating them to farmers can be problematic: investment in training is therefore crucial. This training should be continuous, specifically qualified and targeted to all stakeholders, from farmers to policy makers, including farmers' organizations, technicians, teachers, students and agronomists. This means changing traditional, psychologically and culturally deep-seated attitudes, and modifying seemingly perpetual ways of thinking.

This new paradigm implicates many structures and institutions within and beyond the agricultural sector that must provide assistance to farmers on this new and clearly revolutionary farming strategy. Such a

profound change in family farming will be slow in developing countries, but still possible, as indicated by the promising results obtained over the last 15 years or so.

Following the projects carried out by CIRAD and Southern partners since 1990, under many different ecological conditions (Brazil, Madagascar, Gabon, Côte d'Ivoire, Vietnam, etc.), the French Development Agency (AFD) and partners (French Global Environment Facility, FGEF, and the French Ministry of Foreign Affairs, MAE) have been clearly and jointly committed to promoting this new strategy (Laos, Tunisia, Cameroon, Mali, etc.).

Focus

The living soil: the focus of climate change, desertification and biodiversity concerns

The soil is a loose fragile material that "coats" emerged land worldwide—it is a vital resource for humanity as it is the foundation of agriculture and thus nutrition. It is a precious capital and heritage for everyone, including societies, citizens, farmers, etc. The soil, along with water and the climate, is a key component of terrestrial ecosystems that we live in and belong to. It usually takes millions of years for a soil to become a naturally fertile living substrate for agriculture. As an ecosystem, the soil is the core and first link (metaphorically, of the "food chain"?) of large-scale terrestrial ecosystems and agroecosystems that form on, around and thanks to it. The soil, when it functions efficiently, is at once a "bioreactor", filter, substrate, nourishing recycling medium, water supply and buffer against external stress.

Organic matter is obviously a basic component of the soil because it is a structuring and porosity agent, as well as a nutrient and energy source for its biodiversity (microflora, meso-macrofauna, plants, etc.), while ensuring the resilience and functions of the soil ecosystem. However, this fresh moist organic matter is supplied (in quantity and quality) by the natural and agricultural biomass that returns to the soil. The best that can be done to protect, maintain and improve the quality of a cultivated soil is to keep it permanently covered, to never till it, and to supply it with the most diversified biomass possible. These are the main agroecological principles. This management strategy will enable the soil to produce cost-effectively, while maintaining a sustainable agroecosystem.

Conversely, if farming practices are not changed, soil degradation usually leads to desertification of ecosystems, wasted rainwater, loss of biodiversity and resilience against stress related to pending climate change. This is why the soil is the key common element of current global concerns, which are the focus of three important international conventions (climate change, biodiversity, combating desertification). DMC adoption and dissemination would be one of the best ways to sidestep this impending catastrophe.

For further information…

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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 (reasercher focusing on Southeast Asia)
www.css.cornell.edu/faculty/hobbs

Other websites are also available, especially concerning the situation in North America and Europe. For further information (in French only), see *La gazette des SCV au Cirad*. 31 (June-July 2006): 42-50.

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List of acronyms and abbreviations

- AFD: French Development Agency / *Agence Française de Développement*
- C3ED: Centre of Economics and Ethics for Environment and Development, *Centre d'économie et d'éthique pour l'environnement et le développement*
- CDM: Clean Development Mechanism
- CIRAD: Agricultural Research Centre for International Development, France *Centre de coopération internationale en recherche agronomique pour le développement*
- COP: Conference of the Parties
- CSFD: French Scientific Committee on Desertification *Comité Scientifique Français de la Désertification*
- DMC: Direct seeding mulch-based cropping system
- DPGT: *Développement Paysannal et Gestion de Terroir*, Cameroon
- DRS: Soil protection and restoration
- DT: Tunisian dinar
- ESA: *"Eau-Sol-Arbre"* project, Cameroon
- FCFA: CFA franc
- FGEF: French Global Environment Facility *Fonds français pour l'environnement mondial*
- GNP: Gross national product
- IRD: *Institut de recherche pour le développement*, France
- JRU: Joint research unit
- MAE: French Ministry of Foreign Affairs / *Ministère des Affaires étrangères*
- SODECOTON: *Société de Développement du Coton au Cameroun*
- UNFCCC: United Nations Framework Convention on Climate Change *Convention des Nations Unies sur le changement climatique*
- USD: US dollars
- USDA: United States Department of Agriculture
- UVSQ: University of Versailles Saint-Quentin-en-Yvelines, France *Université de Versailles Saint-Quentin-en-Yvelines*
- WSC: Water and Soil Conservation
- WWF: Global environmental conservation organization *Organisation mondiale de protection de la nature*

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Abstract

Water and soil are the first links of the food chain of ecosystems, and these components in turn nurture the soil with their biomass. Desertification affects both of these key components with a series of consequences that ramify throughout the entire ecosystem, which thus becomes vulnerable, loses part of its biodiversity and hence its resilience and functions. These degraded ecosystems are no longer able to provide stakeholders—especially farmers—with resources and services. Farmers are then forced to overutilize the environment, thus further worsening the desertification process. What could be done to offset this desertification spiral at local and then at higher global scales?

Research and development on cropping systems such as direct-seeding mulch-based cropping systems (DMC) means at least partially meeting this challenge, and then disseminating this technique in Southern countries during the 21st century. DMC is a highly innovative system, central to conservation agriculture and agro-ecological practices. It involves no-till cropping and provides permanent soil protection with both crop residue and companion crops, through crop combinations, yearly sequences or rotations.

Keywords: Desertification, water, soils, resilience, DMC, direct-seeding mulch-based cropping systems, direct seeding, vegetation cover, biodiversity

Résumé

L'eau et le sol sont les premiers supports de la chaîne alimentaire des écosystèmes qui, en retour, par leur biomasse, alimentent le sol. La désertification touche ces deux composantes primordiales, sols et eaux, avec des effets induits sur l'ensemble de l'écosystème qui devient alors vulnérable, perd de sa biodiversité, donc de sa résilience et de ses fonctions. Ces écosystèmes dégradés ne sont plus capables de fournir des ressources et de rendre des services aux hommes, et particulièrement aux agriculteurs. Ces derniers doivent alors surexploiter le milieu, renforçant ainsi les processus de désertification. Comment contrecarrer une telle spirale, d'abord localement, puis globalement, à des échelles supérieures ?

C'est le challenge que prétend relever, du moins en partie, la recherche-développement sur les systèmes de culture en semis direct sur couverture végétale permanente (SCV), puis leur diffusion dans les pays du Sud, au cours du 21ème siècle. Les systèmes SCV sont des systèmes de culture très innovants situés au coeur de l'agriculture de conservation et des pratiques agro-écologiques. Ils permettent de cultiver sans travailler le sol et assurent une protection permanente de ce sol grâce à des résidus de récolte et à l'introduction de couverts végétaux additionnels, en association, en succession annuelle ou en rotation avec les cultures principales.

Mots clés : *Désertification, eau, sols, résilience, SCV, semis direct, couverture végétale, biodiversité*

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