Conservation agriculture, environmental and economic benefits

L. García- Torres[1], A. Martínez- Vilela[2], A. Holgado- Cabrera[3] & Emilio Gónzalez- Sánchez[4]

European Conservation Agriculture Federation (ECAF),
Brussels, Belgium, www.ecaf.org &
Spanish Association for Conservation Agriculture/ Living Soils (AEAC/ SV),
Cordoba, Spain, www.aeac-sv.org;

1. Introduction

This work aims to summarize the main ideas described in the *Workshop on Soil Protection and Sustainable Agriculture* organized by the EU Commission DG Environment and the DG Environmental Quality of the Spanish Ministry of Environment *(Soria, Spain, 15-17 May, 2002)*. The principles on which conservation agriculture is based, its environmental and economic benefits, and its tentative evolution/acceptance in Europe as part of the good agriculture practices/ agri-environmental measures were discussed. Information on the European Conservation Agriculture Federation (ECAF) and its national associations was also given.

2. Principles

Soil is a limited natural resource on which agrarian activities (agriculture, livestock and forestry) are carried out. It is interconnected with other natural resources, which are also essential for human life, such as the air, water, fauna and flora. Soil acts as the most important intermediate and regulating factor most agricultural processes and, by extension, the environmental effects of agriculture. From whence it can be said that if the soil is well managed, the effects of agriculture on the environment will be acceptable and, conversely, if it is badly managed agriculture will deteriorate other resources needed by humans (water, fauna, flora, atmosphere).

Traditional or conventional agriculture bases most of its operations or practices on soil tillage; i.e., inversion tillage such as mouldboard ploughing or disk harrow, or vertical tillage such as chisel, "spiked" harrow and other tools. Soil tillage drastically alters its original structure, breaking up its natural aggregates and burying the residues of the previous crop. So that, the bare soil becomes unprotected and exposed to the action of the wind and rain. Under these circumstances water and soil erosion and sediment runoff are likely to occur. Furthermore, with tillage, soil organic matter and biodiversity content are reduced and unnecessary emissions of CO_2 into the atmosphere take place. It can be said that this tillage agriculture began in the Roman Empire with the development of the Roman plough, and it took place a tremendous increase in the capacity to till the soil in the second half of the 20th century, due to the massive manufacture of high power tractors, capable of actuating heavy implements which are highly aggressive for the soil.

Fortunately, the past few decades has seen the development of ***conservation agriculture*** which attempts to alter the soil profile as little as possible, leaving it permanently protected from the action of the wind and rain with the plant residues from the previous crop (stubble) and/ or with "cover crops", whose mission is precisely the protection of the soil in the periods or phases occurring between the crops planted for economic purposes. Direct sowing, reduced or minimal (minimum) tillage and cover crops in tree plantations are diverse modalities of conservation agriculture.

[1] CSIC Research Professor of the CSIC Institute for Sustainable Agriculture and ECAF President, [2] ECAF Executive Director, [3] ECAF Associated, and [4] AEAC Executive Director.

3. Agro-environment and types of agriculture

The negative effects on the environment caused by conventional agriculture are well known and can be listed as follows:

Soil erosion / desertification
Soil organic matter reduction
Decrease of the biodiversity
Soil compaction
Extra CO_2 emissions into the atmosphere
Lesser storage of water in the soil profile

In this paper attention will be paid to only some of these important items.

Erosion and desertification. The erosion and, by extension, the desertification of the soil are well known problems in Europe and in particular in Spain, and are to a great extent attributable to the abovementioned conventional agricultural practices (soil tillage). In fact, European agriculture is still predominantly based in tillage operation which disaggregated the soil aggregates and leaves it unprotected, exposed to the rain, prone to the sediments runoff and the consequential contamination of surface water, with a very low content in organic matter and in biodiversity, and unnecessarily emitting CO_2 into the atmosphere, among other aspects to be considered. Desertification is one more consequence of this. The solution to these problems is to change the cropping techniques, adopting "conservationist" ones whereby the stubble/ remains of previous crop/ “cover crops” permanently protect the soil. All this technology is already highly advanced scientifically contrasted and, in some European countries and particularly in Spain, partly introduced (10-15%), although there is still a long way to go until acceptable figures in agri- environment are reached.

Organic matter. It should also be mentioned that tillage is the main cause of the emissions of CO_2 from the soil into the atmosphere and, in the long run, of the decrease in organic matter in the soil (Fig. 1 and 2). It can therefore be categorically stated that given that the great majority of European agricultural soils, and Spanish soils in particular, have been tilled for decades their organic matter content is approximately half what they had originally; which in turn entails the use of high doses of fertilizers in order to reach a certain production level.

Biodiversity. It is also very important to point out that soil tillage drastically diminishes the biodiversity of the agrarian medium. It is essential to consider that this biodiversity is constituted by the species living on the soil's surface (for instance, bird populations), in the atmosphere-soil interphase (small mammals and reptiles) and in the soil itself (Table 1). In general terms, the greater part of the above organisms, and especially the organisms living in the soil itself benefit to a great extent from conservationist techniques (no tillage) in comparison to traditional agriculture (soil tillage). To take it further still, the action of the organisms living in the soil is enormously important for maintaining its structure and natural fertility. Hence it has been affirmed that the quality of life (biodiversity) in the soil is what determines its potential productivity (Dr. Victor Jordan, SMI, Great Britain).

Table 1. *Average number of live organisms per hectare of arable soil* (>25 cm). Source: Pimentel *et all*. Science 1995, 1118-25.

Arthropods	1,000 kg
Myceobes	Billions
Seaweed	150 kg
Fungi	2,700 kg
Worms	1,000 kg
Protozoa	150 kg
Bacteria	1,700 kg

An explanatory chart of the interactions of the plant residues/ remains on the soil surface and the environmental advantages of carbon sequestering in the soil which occurs with conservation techniques is indicated in Figures 3 and 4, respectively. From whence, *conservation agriculture* is also known as *carbon agriculture.*

Moreover, also known are the different modalities or types of agriculture developed in the past few years, to a great extent to attempt to respond to the environmental problems of conventional agriculture. Among others, the following can be listed:

Integrated agriculture/ integrated production
Organic agriculture
Extensive agriculture
Conservation agriculture

It is interesting to analyse which environment problems are really resolved by the above types of agriculture and which are not.

Integrated agriculture: this can be understood as that combining or "integrating" the different knowledge existing on the protection, production and physiology of crops, so that the use of phytosanitary products and fertilizers, among other inputs, is the most acceptable possible for the environment. This means, among other positive practices, employing phytosanitary products with the least eco- toxicological impact, and splitting fertilizers applications at several times and at reduced doses in order to diminish as far as possible their leaching. This agricultural modality is included in the environmental measures currently in force in several European countries (Spanish Royal Decree 4/2002, 13^{th} January). However, it should be pointed out that Integrated Agriculture must also incorporate conservationist techniques in order to be effective, facing up to the aforementioned agri- environmental problems caused by conventional agriculture (erosion/ desertification, contamination of surface waters, and low soil O.M. content, among others).

Organic agriculture: this is defined as that which does not use synthetic pesticides or fertilizers inputs. It is regulated by a EU Directive and by numerous national regulations. From an environmental point of view its potentially positive effect is the absence of pesticide residues in foods. However, it should be remembered that this problem does not exist in most of the agricultural crops/ systems, in which, even when applying phytosanitary/ pesticides products, either no residues of them are detected, or at very low doses, with no effects on the environment, including humans and the fauna in general. In other words, the regulations in the use of phytosanitary products guarantee their eco- toxicological innocuousness with a wide margin of safety. On the other hand, it should be emphasized that *organic agriculture does not offer any solution to the main environment problems mentioned above* (erosion/ desertification, pollution of surface waters and low content of soil organic matter, among others) unless it also incorporates the soil protection conservationist techniques. Furthermore, the non-use of synthetic fertilizers and pesticides normally signifies a decrease in production and quality.

Extensive agriculture aims to reduce the consumption of fertilizers and pesticides. It is included in the agri- environmental measures currently in force in some European countries (Spanish RD 4/2002, 13th January). Its potential environmental proposals, benefits and limitations are similar to those of integrated agriculture. It therefore also must incorporates conservationist techniques in order to tackle the main agri- environmental problems mentioned above (erosion/ desertification, contamination of surface water and low organic matter content of soils, among others). Otherwise, the environmental achievements of extensive agriculture would be highly limited and difficult to follow up.

4. Conservation Agriculture economy v. diverse agricultural operations

In this section we refer to the economic and environmental advantages of various conservation agriculture operations in their top modalities: direct sowing in annual crops and crop cover in perennial crops.

Fertilization. Leaving the crop residues over the soil surface and not tilling the soil for several years increases considerably the organic matter content on the top layer, which provides a much greater mobilization of nutrients (Table 2), permitting a reduction to a great extent in fertilizer doses at medium/ long term (3-5 years) since initiating these techniques, among other excellent benefits. It should be pointed out fertilization is one of the most important crop inputs/ expenses in the production situations and agrarian systems.

Table 2. *Mobilization of nutrients in conservation agriculture (non tillage, NT) in comparison to conventional agriculture (tillage /ploughed soils*, *T*). Source: *Conservation Technology Information, CTIC Partners, 2000, no 1, p. 7, University of Purdue, Indiana, USA)*

Soil depth cm	*Carbon (%)*		*Nitrogen (%)*		*Phosphorous (ppm)*	
	NT	*T*	*NT*	*T*	*NT*	*T*
0-5	2.5	1.0	0.3	0.1	100	20
10-15	1.3	1.0	0.2	0.1	10	40

Energy savings. A great part of the economic advantages of conservation agriculture over conventional agriculture is due to the saving in energy signified by the absence of tillage in the soil and which is reflected in Table 3. Also, Table 4, for different crops or cropping systems, shows the average saving in energy, time or money of conservation agriculture in comparison to the conventional technique according to estimations by Hernanz & Sánchez-Girón, 1997, Polytechnique University, Madrid. Extensive information on the economic advantages of conservation agriculture is given on the FAO WEB site, as follows: *www.fao.org/waicent/agricult/ags/AGSE/present/conser.HTM*

Table 3. *Average energy consumption of some tillage operations (John Nalewaja, 2001)*

Operations	*Diesel consumption (l/ha)*	*Energy consumption (kcal/ ha)*
Mouldboard plough	16.81	256,669
Cultivator	5.61	52,285
Disk harrow	6.55	61,046
"Chisel" plough	8,89	82,855
Harrow	3.37	30,476
Pass with no soil tillage	0.94	8,761

Table 4. *Average saving in energy, time or money of conservation agriculture in comparison to conventional agriculture* (Hernanz & Sánchez- Girón, 1997, Polytechnique University, Madrid).

Average energy saving	15-50% 31.5 L gas oil $year^{-1}$
Olive tree plantations	60-80 L gas oil $year^{-1}$
Average monetary saving in annual crops	40-60 EUROS $year^{-1}$
Average monetary saving in machine maintenance	97 EUROS $year^{-1}$

5. Conservation agriculture: the agri- environmental and economic revolution of the 21st century

Conservation agriculture is highly developed in different countries like the U.S.A., Canada, Argentina, Brazil and Australia (Figure 5). The U.S.A. was the first country, which began to support it in 1986 as an efficient means to face soil erosion. Worldwide it has been estimated that only in annual crops with direct sowing possibly 80 million ha. has been reached (4 times the agricultural surface of Spain and a little over 150% of its total surface). There has been a spectacular advance in this cropping system in Argentina and Brazil in the past 8-10 years, with over 12 and 17 M ha of direct drilling/ no till in annual crops, respectively.

In Europe, however, the development of conservation agriculture has been somewhat slighter up to now than in the countries cited. Spain and Portugal with approximately 15-20% and 10%, respectively, of its agricultural surface cultivated in the conservation system are pioneering European countries in this respect. Among the reasons for the slow adoption of conservation agriculture in Europe in the decade from 1990-2000 the following can be mentioned: a) the low level of information on the agri- environment, both on the part of the administrations and of farmers; b) little institutional support from the administrations; and c) little pressure in economizing on costs on the part of the farmers, which they could achieve by the adoption of the conservationist techniques. On the contrary, farmers, by receiving "per surface" or "compensatory" agricultural subsidies since the beginning of the 1990's, have been obtaining acceptable incomes without any notable environmental obligations; and d) little conservationist technology transference.

In spite of the above, it is highly predictable that in the next few years conservation agriculture will be adopted to a great extent in Europe. The agri- environmental awareness by the administrations, and the expected development of the EU Commission Communication on Soil Protection will undoubtedly favour conservation agriculture as an effective agricultural modality to tackle agri- environmental challenges/ problems. This, together with the reduction in "per surface" or "compensatory" agricultural subsidies anticipated in the new CAP, will increase the need of farmers to reduce costs and consequently to adopt conservation techniques.

The massive adoption of conservation agriculture in Europe is a truly revolutionary challenge, which is highly positive for the environment and the economy. This change is not easy for farmers as it signifies a new training in important techniques/ operations for the crop management. Namely, an updating of knowledge and of new techniques, such as direct sowing and the use of herbicides in the handling of plant covers and the control of new weed species, as well as a certain amount of investment in the modernization/ bringing up to date of farm machinery. All the above is in keeping with the commercial interests of some agrarian firms, but not of others.

6. ECAF

The European Conservation Agriculture Federation (ECAF) is made up of a group of European scientists, technicians and farmers interested in the transfer of technology and the adoption of conservationist practices. These, as previously described, consist essentially of altering the surface layer of the soil as little as possible and keeping the soil surface permanently protected by plant residues/ stubble from the previous crop and/or by crop covers. ECAF is not related to any commercial products or equipment. At present, fourteen national associations from the following countries belong to ECAF: Germany, Belgium, Denmark, Slovakia, Spain, France, Finland, Great Britain, Greece, Hungary, Italy, Ireland, Portugal and Switzerland.

AEAC.SV*, Asociación Española de Agricultura de Conservación. Suelos Vivos (AEAC.SV) SPAIN, Alameda del Obispo, s/n Apartado 4084 14080 Córdoba (Spain); e-mail: amartinez@aeac-sv.org; Web: www.aeac-sv.org*

AIGACoS*, Associazione Italiana per la Gestione Agronomica e Conservativa del Suolo (AIGACoS) ITALY, località Zimarino - S.S. 16 Nord, 240 66054 VASTO (CH) - Italy*
e-mail: pisante@cotir.it; Web: www.aigacos.it

APAD, *Association pour la Promotion d´une Agriculture Durable (APAD) FRANCE*
6, rue Roger Bacon 75017 Paris (France); E-mail: apadorg@compuserve.com Web: www.apad.asso.fr

APOSOLO *Associação Portuguesa de Mobilização de Conservação do Solo (APOSOLO) PORTUGAL, Universidade de Évora Deptº de Fitotecnia, P-7002-554 ÉVORA E-mail: gb@dfit.uevora.pt Web: www.aposolo.pt*

***BARACA**, Belgian Association in Research Application on Conservation Agriculture (BARACA) BELGIUM, Ministère des Classes Moyennes et de l'Agriculture,Centre de Recherches Agronomiques de Gembloux Département Génie Rural,*
Chaussée de Namur, 146, 5030 Gembloux. BELGIUM

***CAIR**, Conservation Agriculture Ireland (CAIR),Unit C2, Dunshaughlin Business Park, Dunshaughlin, Co. Meath,IRELAND; E-mail: john.b.geraghty@pharmacia.com*

FINCA, Finnish Conservation Agriculture, Myllytie 169, 27800 SÄKYLÄ, FINLAND / e-mail: agro@propax.fi

FRDK, *Foreningen for reduceret jordbearbejdning i Danmark (FRDK), DENMARK,* Samsogade 3, DK-8700 Horsens Denmark; E-mail: BeA@lro.dk. Web site: www.frdk.dk

***GKB**, Gesellschaft für Konservierende Bodenbearbeitung (GKB) GERMANY, Dorfstrasse, 9 13051 Berlin (Germany); E mail: jana.epperlein@rz.hu-berlin.de; Web: www.gkb-ev.de*

***HACA**, Hellenic Association for promotion of Conservation Agriculture (HACA) GREECE, Univesity of Thessaly Fytoko Street, N. Ionia (Magnisis) 34446 Greece*, *E.mail: gemtos@agr.uth.gr*

***TMME** Hungary Conservation Agriculture Association, e-mail: pupika@axelero.hu*]

***SMI,** UK Soil Management Initiative (SMI) UNITED KINGDOM, The UK Soil Management Initiative Ltd, 1 The Paddocks, Powey Lane, Mollington, Chester CH1 6LH, UK; vwljordan@tinyworld.co.uk; Web: www.smi.org.uk*

***SNT**, Swiss Soil Conservation Association (SNT Swiss No-Till) SWITZERLAND*
Baumgartenstrasse 33, CH-3018 Bern, Phone: 0041-31-991 50 07; e-mail: sturny@no-till.ch

***SNTC**, Association for development of no-tillage technologies in plant production) SLOVAK NO-TILL CLUB (SNTC), SLOVAK REPUBLIC, VURV, Bratislavska cesta 122, 921 68 Piestany, Slovak Republic; E-mail: lehocka@vurv.sk*

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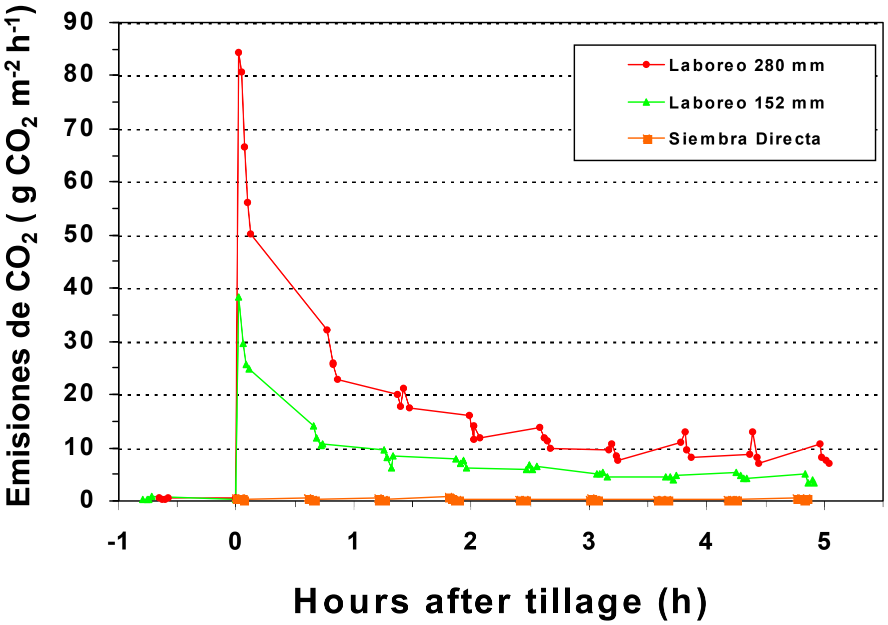
Figures

Fig. 1. Emissions of CO2 into atmosphere due to tillage



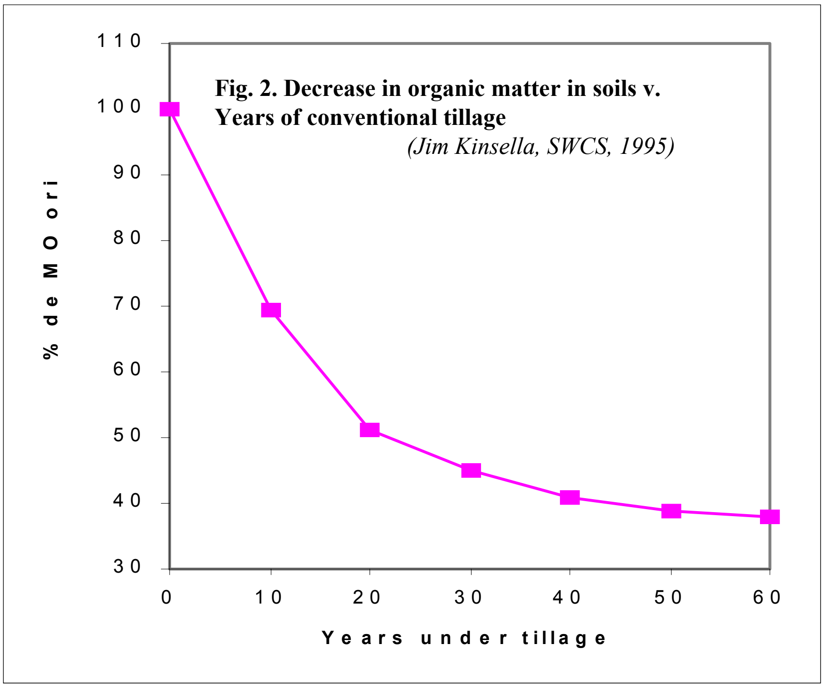


Fig. 2. Decrease in organic matter in soils v. Years of conventional tillage
(Jim Kinsella, SWCS, 1995)

Fig. 3Interactions of plant residues on the soil

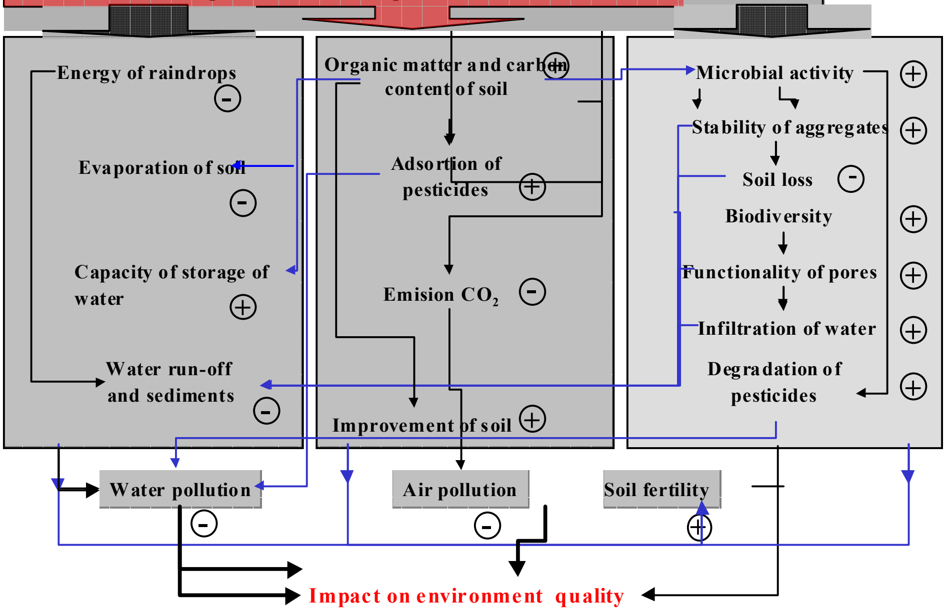


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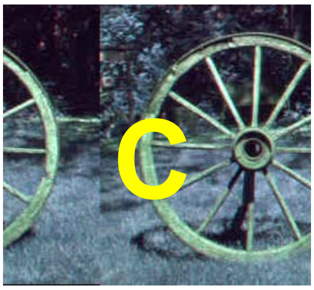
Fig. 4.Sequestering of Carbon in soil

Environmental advantages

- Increases storage capacity and water usage efficiency
- Increases capacity of cationic exchange
-Reduces soil erosion
- Improves water quality
- Improves infiltration, less runoff
- Diminishes soil compaction
- Improves soil structure
- Reduces air pollution



Carbon

The central axis of environment quality

- Reduces fertilizer application
-Increases regulating capacity of soil
- Increases biological activity
-Increases cycle and storage of nutrients
- Increases diversity of microflora
- Increases adsortion of pesticides
-Gives soil a good appearance
- Increases capacity to manage manure and other waste
- More fauna

(Don Reikoski, WCCA, 2001)

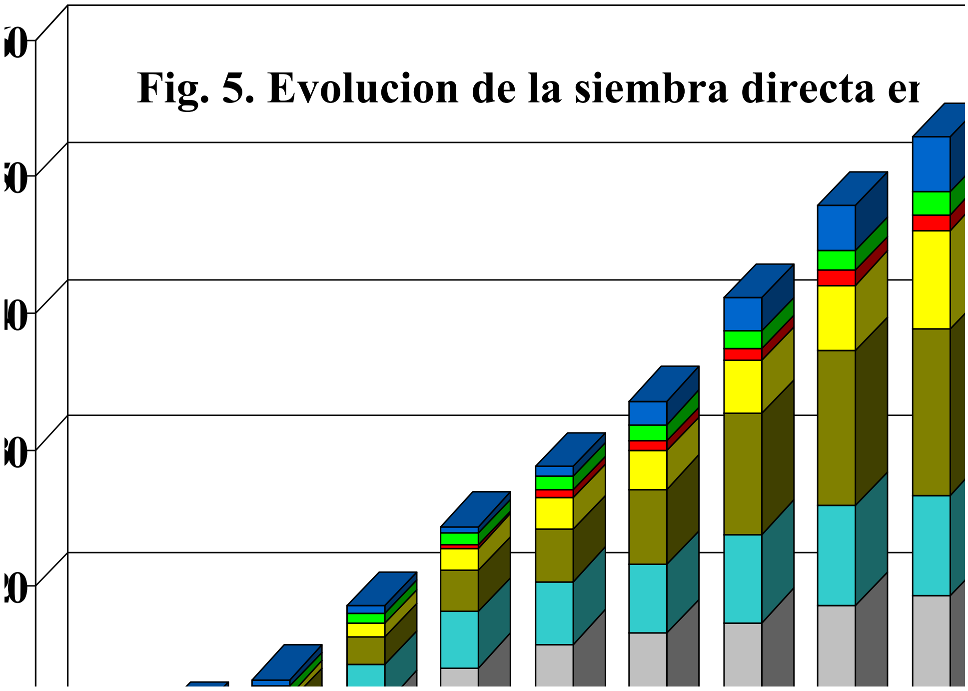


Fig. 5. Evolucion de la siembra directa er