Conservation Agriculture in Europe: Environmental and Economic Perspectives

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Abstract

In Europe, soil degradation due to erosion and compaction processes is probably the most important environmental problem caused by conventional agriculture, seriously affecting nearly 157 million hectares. In fact, *conventional agriculture*, mainly characterized by straw burning and/or removing and intensive tilling, is still generally used in Europe and has consistent negative effects on soil, water and air quality, global climate, biodiversity and landscape. *Conservation agriculture* refers to several practices such as direct sowing/ no-tillage, reduced tillage/ minimum tillage; non- or surface- incorporation of crop residues and establishment of cover crops in both annual and perennial crops. Generally, with conservation agriculture the soil is protected from rainfall erosion and water runoff; the soil aggregates, organic matter and fertility level naturally increase, and soil deformation under heavy wheel load is reduced. Furthermore, less contamination of the surface water occurs, the emissions of CO_2 to the atmosphere are reduced and the biodiversity consistently increases.

A strong body of scientific and technological research supporting the environmental benefits and agronomic performance of conservation agriculture has been developed world-wide in the past few decades. Furthermore, the widespread adoption of conservation agriculture in the last decade has been consistently increasing in several countries (Argentine, Brazil, Canada, USA, among others) but notably not in Europe. The EU greatly needs to change its agricultural technology from one that destroys its soil (conventional) to one those conserves, and even "regenerates", the soil, water and air resources (conservationist).

Keywords: conservation agriculture, cover crops, CO_2 emissions, organic matter, soil degradation, water quality.

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1. Introduction

The significance of agriculture for the environment in the European Union is illustrated by the fact that of the total territory of the EU 50.5% is agricultural land. Indeed, there is a significant interdependence between agriculture and environment (EEA, 1998). The Common Agricultural Policy (CAP) has promoted the modernisation of agriculture in Europe. However, this modernisation has been accompanied by damaging effects on the environment (EEA, 1998). Conventional agriculture, still generally used in Europe, has consistently negative effects on the air and the global climate, water (contamination by sediment, nitrates and pesticides), soil (erosion and degradation), landscape, and biodiversity (EEA, 1998). The objective of this report is to briefly outline the important environmental problems caused by conventional agriculture in Europe and to illustrate how they may be overcome through the adoption of the conservation agriculture techniques.

2. Conventional agriculture *vs.* Conservation agriculture: an environmental overview

Conventional agriculture is generally harmful to the environment. It includes practices such as crop residue burning or deep soil inversion by tilling to control weeds and to prepare the seedbed. As will be indicated later, these techniques considerably increase soil deformation by compaction, erosion and river contamination with sediments, fertilisers and pesticides. In addition, conventional agriculture techniques increase the emission of CO_2 into the atmosphere, contributing to global warming and reduce the sustainability of agriculture by lowering soil organic matter and fertility, along with further negative environmental effects (e.g. a decrease in biodiversity).

Conservation agriculture refers to several practices that permit the management of the soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from degradation processes (e.g. soil erosion and compaction). Direct sowing (non-tillage), reduced tillage (minimum tillage), non – or surface-incorporation of crop residues and establishment of cover crops in perennial woody crops (of spontaneous vegetation or by sowing appropriate species) in perennial woody crops or in between successive annual crops, are some of the techniques, which constitute conservation agriculture. Generally, *conservation agriculture* includes any practice that reduces changes or eliminates soil tillage and avoids residues burning to maintain enough surface residues throughout the year. As will be indicated later, the soil is protected from rainfall erosion and water runoff; soil aggregates are stabilised, organic matter and the fertility level naturally increase, and less surface soil compaction occurs. Furthermore, the contamination of surface water and the emissions of CO_2 to the atmosphere are reduced, and biodiversity increases.

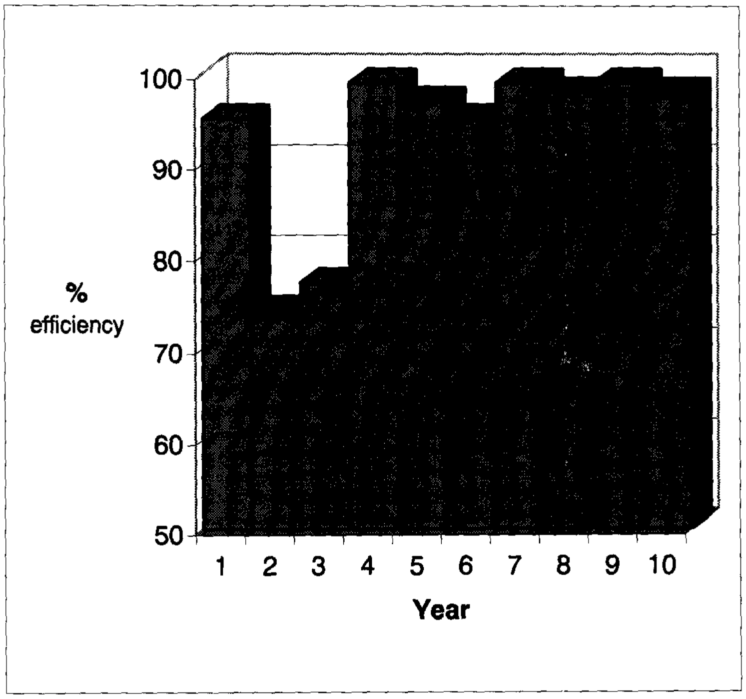
2.a. Soil degradation

Soil erosion is a major environmental threat to the sustainability and productive capacity of conventional agriculture world-wide. Indeed, during the last 40 years, nearly one-third of the world's arable land has been lost to erosion and continues to be lost at a rate of more than 10 million hectares per year (Pimentel et al, 1995). In Europe, soil erosion is a serious problem in many areas, affecting all countries to some extent (Van Lynden, 1995). About 115 million hectares (12% of the total European land area, over twice the size of France) are suffering from water erosion and 42 million hectares (4% of the total European land area) from wind erosion (Oldeman et al, 1991). Around 25 million hectares are seriously threatened by erosion in Western and Central Europe (De Ploey et al, 1991). Furthermore, in the Mediterranean area, soil erosion and degradation is even more severe. In this area water erosion can result in the loss of 20 to 40 tons per hectare of soil in a single storm, with more than 100 ton per hectare in extreme events (Morgan, 1992). In Spain, over 50% of the agricultural land is classified as having a medium to high risk of erosion (MOPU, 24), and in its Southern region this figure reaches over 70% (Council for the Environment, Regional Administration Andalucia, 1996).

The average soil erosion rates in Europe (about 17 ton per hectare per year) greatly exceed the average rate of soil formation of about 1 ton per hectare per year (Troeh et al, 1993). Further, soil erosion and degradation in Europe is increasing (Brown et al, 1996; Lal, 1997), thereby increasing the risk of desertification in the most vulnerable area (EEA, 1998). Conventional agricultural intensification (increased mechanisation and ploughing) over the past 50 years has largely contributed to this trend, particularly in Western Europe.

The driving forces for erosion in Europe are mainly cropping systems that leave the soil surface bare during the rainy season and the burning of crop residues. Excessive tillage as well as tilling during low soil-moisture conditions results in the deterioration of soil structure and an increasing susceptibility to erosion (EEP, 1998). During the 1950's and 1960's terracing and cropping that followed contour lines, although costly and/ or only partly effective, were recommended to reduce erosion. In the last few decades there have been a large number of scientific reports developing and supporting conservation agriculture techniques: simply not burning the straw, not ploughing/ tilling and leaving the straw over the soil. These practices are very effective (>90-95%) at drastically reducing soil erosion (Figure 1).

Figure 1. Efficiency (%) of direct sowing/ no tillage in soil erosion reduction as compared to conventional tillage (ploughing) in several years in Indiana (USA) (Towery, 1998).



2.b Soil quality

Soil quality is largely governed by organic matter content, which is dynamic and responds effectively to changes in soil management. Apart from areas with a heavy surplus of animal manure, the organic matter content of many cultivated soils across Europe is diminishing as a result of modern intensive agriculture (EEA, 1998). For example, the Soil Survey and Land Research Centre of the UK has shown that under conventional tillage, from 1980 to 1995, there has been a decrease in the number of sites with a high organic content (>4%) and a concomitant decrease in those with organic carbon content of below 4% (Fig. 2). Others research groups have obtained similar results; generally, in about 20 years of intense tillage most agricultural soils lose 50% of soil C (Figure 3) (Kinsella, 1995).

Figure. 2 Topsoil organic carbon content (%) of cultivated soil in England and Wales, 1980 and 1995. Data from the Soil Survey and Land Research Centre, MAFF, UK, 1997 (cited in Pimentel, 1995)

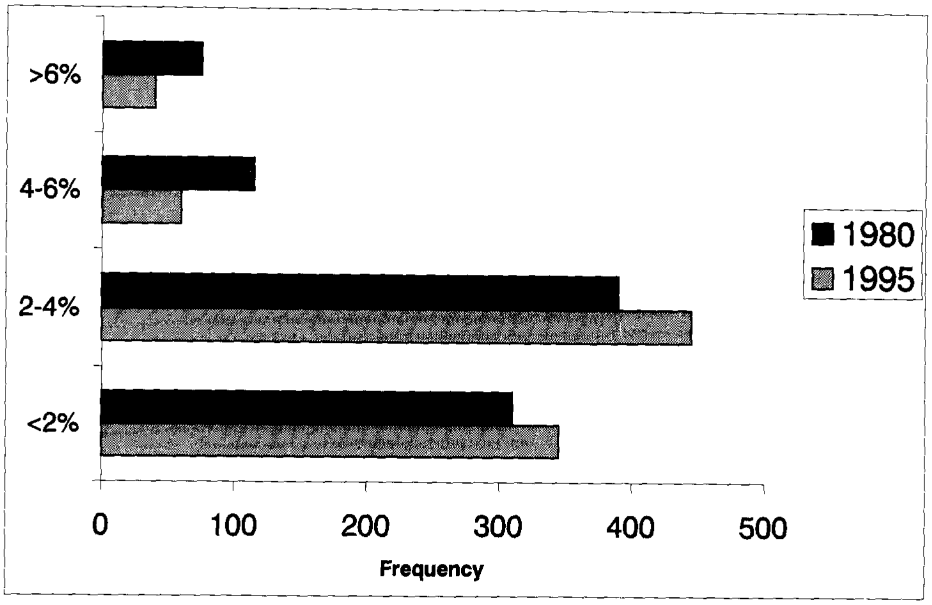
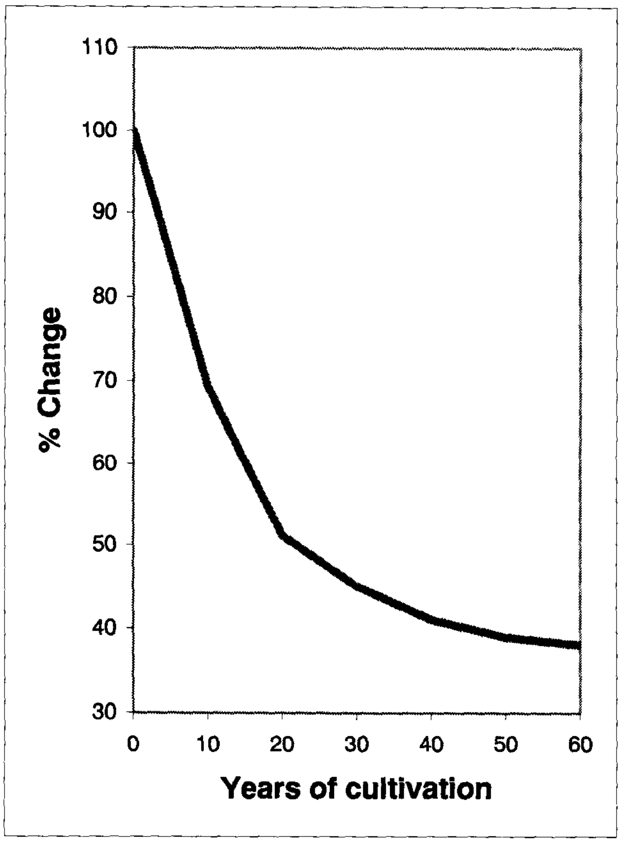
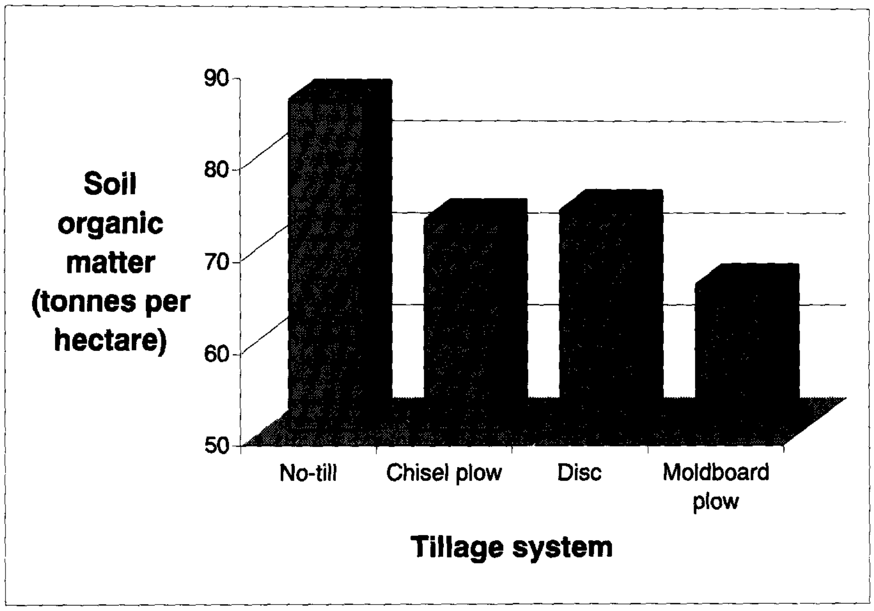


Figure 3. Change of soil organic matter content with years of cultivation (Kinsella, 1995)



A decline in organic matter content will affect soil structure and stability, water retention properties, buffering capacity, biological activity and the retention and exchange of nutrients. It may also in the medium and long term, make the soil more vulnerable to erosion, compaction, acidification, salinisation, nutrient deficiency, and drought (EEA, 1998). In contrast, it has been widely reported that when changing from conventional (mouldboard tillage) to conservation agriculture (direct sowing/ no-tillage) the soil increases its organic matter content over time (Figure 4) (Gonzalez, 1997; Gregorich et al, 1995).

Fig 4. Organic matter content at two depths after 18 years of various tillage treatments (no-till, chisel, disc and mouldboard ploughing) of soil growing corn in Ontanio, Canada (Gregorich et al, 1995).



Soil water content is often a very important limiting factor in agricultural productivity, particularly under dry land condition. Many authors have reported that conservation techniques (direct sowing) increase the water content in the soil profile in comparison with conventional techniques (ploughing/ tilling), particularly in dry years (Berengena, 1997). The straw over the soil decreases soil water evaporation, while each tillage operation increases it.

2.c. Water quality

Soil sediments. These are by far the most important contaminants of surface water, affecting aquatic ecosystems by reducing sunlight penetration to aquatic plants and fouling the habitats of fish and other organisms (Christensen, 1995). According to this source, other water contaminants in decreasing order are nutrients, pathogens, organic matter, metals and pesticides (Figure 5).

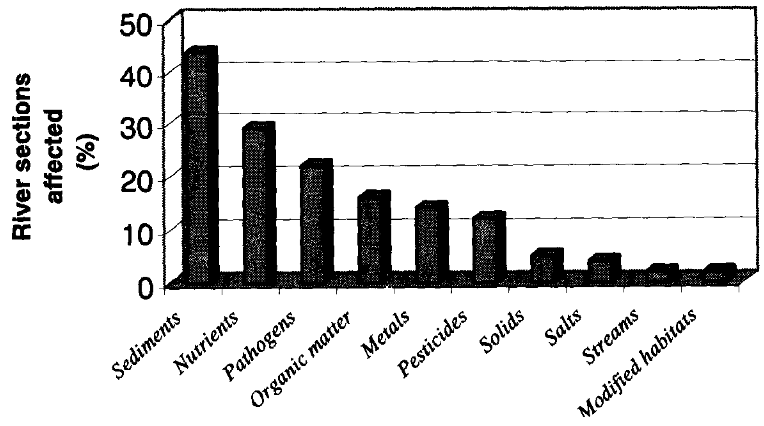


Figure 5. Surface water contaminants in decreasing order (Christensen, 1995).

Soil sediments transported in the surface water from eroded agricultural land cause important off-site problems. Indeed, off-site soil erosion economic damage is nearly 40% of the total cost of the erosion (Pimentel et al, 1995). Thus, by implementing conservation agriculture the rest of society would also benefit when the off-site effects of erosion are avoided, up to an estimate of 32 EUR per hectare of agricultural land. If off-site and on-site erosion costs are combined, the total cost of erosion from agriculture in USA were estimated at about 85.5 EUR per hectare of cropland annually (Pimentel et al, 1995).

Conservation tillage systems greatly reduce soil erosion, with reductions of up to 90 percent or more with direct sowing/ no-tillage (Towery, 1998) and over 60% from non-inversion tillage (6) as compared to conventional tillage. Consequently, the adoption of conservation systems significantly improves surface water quality by reducing sediment.

The crop surface residues that characterize conservation agriculture help to intercept nutrients and chemicals and keep them in place until they are used by the crop or degrade into harmless components. Indeed, conservation agriculture also reduces runoff, tightly adsorbed chemicals carried in sediment, such as certain pesticides, ammonium-nitrogen, and sediment-bound phosphate (Fawcett, 1995). For example, in non-inversion tilled soils, herbicide emissions in drain water discharges have been substantially reduced, as have total oxidised nitrogen (>85%) and soluble phosphate (> 65%) emissions (Jordan et al, 1997). Further, a comprehensive comparison of tillage systems shows that, on average, conservation agriculture (direct sowing/ no-tillage) resulted in 70% less herbicide runoff, 93% less sediments and 69% less water runoff than mouldboard ploughing- a real boon for improving water quality (Fawcett, 1995).

2.d. CO_2 emissions and global warming

European annual mean air temperatures have increased by 0.3-0.6° C since 1990, and climate models predict further increases (EEA, 1998). It is well documented that fossil fuel burning, because of the CO_2 emissions, is the dominant driving force in enhancing global warming. Generally, the critical problem is stabilisation of CO_2 concentrations.

The agriculture sector world-wide accounts for about one fifth of the annual anthropogenic increase in greenhouse forcing, producing about 50 to 75% of anthropogenic methane and nitrous oxide emissions and about 5% of anthropogenic CO_2 emissions (Cole, 1996). Deforestation, biomass burning and other land use changes account for an additional 14%. Conventional agriculture is one of the main drivers of climate change. Ploughing or soil inversion is a principal cause of CO_2 emission from cropland (Lal, 1997). There is scientific evidence that soil tillage has been a significant component of the increase in atmospheric CO_2 which has occurred in the last few decades.

Historically, intensive tillage of agricultural soils has led to substantial losses of soil C that range from 30% to 50% (Davidson, 1993). These CO_2 losses are related to soil fracturing which facilitate the movement of CO_2 out of the soil and oxygen into it.

Conversely, under conservation agriculture (direct sowing/ no-tillage) the C soil content increases annually at a rate of 1.0 tonne per hectare or higher (Arrue, 1997). Calculations suggest that 100% conversion to no-till agriculture in Europe could mitigate all fossil fuel-carbon emissions from agriculture in Europe, this is equivalent to only about 4.1% of total anthropogenic CO_2-carbon produced annually in Europe and to 0.8% of global annual anthropogenic CO_2-carbon emissions (Smith et al, 1998).

2.e. Biodiversity

Conventional agriculture leaves the soil bare for long periods of time. Lack of quality habitat and sparse nesting cover are a problem for many bird species. In contrast, high-residue crop production systems can provide food and shelter for wildlife at critical times. That is why conservation agriculture, which provides a high level of crop residues, is attractive and valuable for helping several forms of wild life (birds, small mammals, reptiles) to thrive in agricultural areas. Several studies have shown that no-till fields have higher densities of birds (and nests) and are used by a greater variety of bird species during the breeding season than tilled fields (Best, 1995). Indeed, conservation agriculture provides better feeding (microarthropods, wild plant seeds) for birds over a longer period of time, generally resulting in a more diverse and greater population of birds (Valera et al, 1997).

3. Comparative economics of conservation *vs.* conventional agriculture

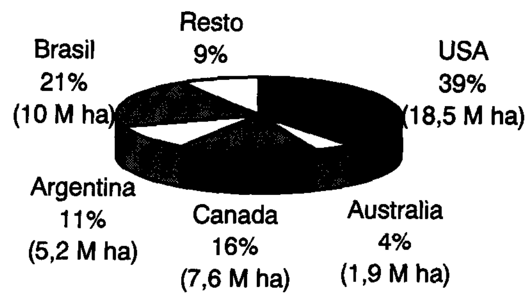
In conventional agriculture, tillage operations require considerably higher inputs in machinery investment and maintenance, fossil combustibles and labour inputs as compared to conservation agriculture, especially direct sowing/ no-tillage. For example, in no-till olive crops a saving of about 60 to 80 litres of fuel and 3 to 5 hours of labour per hectare annually is estimated as compared to conventional tillage (Castro, 1999). Generally, conservation agriculture reduce the energy consumption of farming operations and increases energy productivity –this is the yield output per energy input- in the range of 15%-50% and 25%-100%, respectively (Hernanz et al, 1997).

Direct drilling/ no-tillage requires as little as one pass for planting compared to two or more tillage operations plus planting for conventional tillage. Fewer passes save an estimated 97 EUR per hectare on machinery depreciation and maintenance costs (Pimentel et al, 1995). That is, about 1950 EUR savings on a 200 hectares farm. Direct sowing/ no-tillage also permits a fuel saving of an average of 31.5 litres per hectare annually compared to conventional tillage systems (Pimentel et al, 1995). These savings normally compensate for or exceed the extra costs of conservation tillage (application of herbicides and direct sowing machinery). The annual cost reduction in direct sowing of annual crops compared to conventional tillage ranges between 40 and 60 EUR per hectare in Southern Europe conditions (Arnal, 1997). Therefore, in some areas farmers who adopt conservation techniques are strongly motivated by cost-savings. This is clearly the case of geographical regions where cropland is not highly erodible and/ or of countries where agriculture is not subsidised by the government, such as Argentina and Brazil.

4. Current world-wide state of conservation agriculture

On a worldwide basis, the diverse modalities of conservation agriculture have grown dramatically in the past 15 years (Figure 6). With regard to annual crops, they were practised on 1996 in 78 million hectares, and this has continuous to grow. Direct sowing/ non-tillage has advanced in the past ten years from 6 to 47.5 million hectares, world -wide.

Fig. 6. Direct sowing in annual crops wold-wide.1997 (total 47.5 millions hectares)



The USA has been the pioneer country and is still today the leader in conservation agriculture (called there conservation tillage with reference only to annual crops. The strong support of subsequent USA administrations for conservation tillage through the implementation of the Farm Bills of 1985, 1990 and 1996 Farm Bills are worthy of noting. In 1997, in 37% of the 120 million hectares were cultivated using these techniques, maintaining over 30% of the soil covered with stubble whilst conventional tillage (under 15% of residue coverage) diminished by up to 36.5%. There were over 18 million hectares of direct sowing/ no tillage. Other pioneer countries in conservation agriculture are Australia, Canada, Brazil and Argentina. It should be pointed out that in the latter two countries, where agriculture is not subsidised by the government, direct drilling has increased from only a few thousand hectares in 1992 to over 12 and 7.5 million hectares in 1998.

Unfortunately, agricultural conservation in Europe is at the moment very little developed (estimated at <1-2% of its agricultural land), far behind the countries previously mentioned. However, the validity of these methods has already been demonstrated in most European agricultural situations.

6. Conclusions and final comments

Soil erosion and degradation and related environmental problems of agricultural land are very important in Europe. Up to now the Common Agricultural Policy has not really supported sound environment friendly agricultural practices. In the light of present technology, conservation agriculture can efficiently contribute to the solution of environmental problems across Europe's agricultural land base. These problems are basically the erosion and the loss of the production capacity of soils, the pollution of surface water, the emission of CO_2 and other greenhouse gases, and the progressive global warming of the atmosphere, and the loss of biodiversity. Furthermore, conservation agricultural techniques can fit into the "continuum" of different farming systems that are appropriate within the EU. Therefore, at this regard a tremendous effort at the administrative and technology transfer level is needed in Europe.

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