TECHNOLOGICAL INNOVATION, AGRICULTURAL MECHANIZATION AND THE IMPACT ON THE ENVIRONMENT: SOD SEEDING AND MINIMUM TILLAGE

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ABSTRACT

This research deals with aspects of mechanisation, through the analysis of two conservative techniques, sod seeding and minimum tillage (recently introduced in the Sicilian agricultural context), which are a fine example of innovation with low environmental impact. The first chapter of this research document looks at mechanisation as a technological innovation, focusing attention on the relationship between the innovation process (new technologies) and the development of sustainable agriculture. The second chapter of this research is based on illustration of results of some representative farms and deals with the effects that the use of these techniques may have on the organisation of the farms agricultural activities and the economic advantages of their use. We have briefly examined effects on soil, the main technical limitations and economic implications.

RÉSUMÉ

Cette recherche porte sur les aspects de la mécanisation, à travers l'analyse de deux techniques de conservation, le semis direct et la culture minimale (récemment introduites dans le contexte agricole de la Sicile), qui représentent un joli exemple d'innovation à faible impact environnemental. Le premier chapitre de ce travail de recherche considère la mécanisation une innovation technologique concentrée sur la relation entre le processus d'innovation (nouvelles technologies) et le développement d'une agriculture durable. Le deuxième chapitre de cette recherche est basé sur l'illustration des résultats de quelques exploitations agricoles représentatives et s'occupe des effets que l'utilisation de ces techniques pourrait produire sur l'organisation des activités agricoles de l'exploitation et les avantages économiques de leur utilisation. On a brièvement examiné les effets sur le sol, les contraintes techniques minimales et les implications économiques.

INTRODUCTION

The diffusion of intensive monocoltural systems, based on the wide spread use of chemical substances (such as fertilizers, pesticides, herbicides) and on heavy mechanization, have caused serious problems which affect the make up of the soil, predisposing the environment to degradation and the problem of drying up, subjecting it to the process of desertification (1) and fallow.

This research deals with aspects of mechanization, through the analysis of two techniques, sod seeding and minimum tillage, which are a fine example of innovation with low environmental impact, particularly suitable for areas which risk desertification.

The first chapter of this research document looks at mechanization as a technological innovation, focusing attention on the relationship between the innovation process (new technologies) and the development of sustainable agriculture. It also focuses on the use of heavy machinery and environmental impact, looking at the agricultural ecosystem: damage to flora and fauna and the landscape as a whole.

We have examined two techniques: "no tillage" and "minimum tillage", recently adopted in Sicily for the cultivation of cereals (wheat).

We have briefly examined effects on soil, the main technical limitations and economic implications.

The second chapter of this research is based on a more thorough examination and deals with the effects that the use of these techniques may have on the organization of the farms agricultural activities and the economic advantages of their use (2).

1. THE DEVELOPMENT OF NEW AGRICULTURAL SYSTEMS AND THE ROLE OF MECHANIZATION

The wide spread use of mechanization is one of the most interesting phases of development which greatly influenced agriculture in the 19th century particularly during the second half of the 20th century (3).

Mechanization has played an important role in the development of modern agriculture, especially looking at the agricultural model which has dominated recent decades of agricultural history in Italy and other western countries. Mechanization is linked to a healthy period of development in which there were various structural changes in agriculture and in the economy.

The increase in the use of agricultural machinery is particularly evident in recent decades: there has been an increase both in the number of machines and in the amount of energy consumed.

This is due to a new trend in national politics to pro-

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(1) The United Nations Organisation defines desertification as follows: 'degradation of cultivable terrain in arid, semi-arid and dry sub-humid areas. This is caused by several factors, among them, climatical factors and human activity' (Earth Summit + 5, Special Session of the United Nations General Assembly for the Revision and Evaluation of the Enforcement of Agenda 21, New York, 1997). The problems related to the fight against desertification are of great interest to the northern basin of the Mediterranean, particularly in south-eastern Spain, Portugal, the French Mediterranean coast, southern Italy and the Italian islands, most of Greece, part of Turkey. The causes are mainly linked to agricultural and pastoral activity.

(2) Farms should not only focus on economic gains, but also on gains in terms of life style and future hopes.

(3) In Italy, agricultural machinery began to be widely diffused particularly after the second world war.

mote European community incentives to buy machinery.
We must remember that until the 1992 reform the trend in Community Agricultural politics privileged the quantitative aspects of production, focusing less on looking at the merits of mechanization, we must take into account that there is still room for improvement.
As far as sustainable agriculture is concerned, one improvement may be to reduce machinery or to use it more effectively.
This would be more productive in the long term. As well as usual problems associated with traditional farming methods, the use of machinery on the flat and in the hills (where there is a greater use of machinery) has caused some serious problems.
It's worth noting that the use of machinery often involves the removal of woods, hedgerows and meadows. These areas are vital to birds, insects, rodents, etc.
The use of machinery hinders normal biological regeneration of the soil, deteriorates its quality and causes compression, which leads to soil erosion and in time ruins the rural landscape.
At present, the organisation of farms requires an extended use of agro-mechanical machinery, we mustn't forget the impact this has on the environment.
Today, the European Community safeguards the environment by adopting sustainable farming methods.
In line with this, the tractor industry produces high technology machinery specifically for a particular kind of tillage, which limits impact on the agro-forest ecosystem.

Sod seeding, used in Italy for autumn-winter cereal cultivations (second seeding for maize), is a good example of alternative sustainable agriculture (4).

1.1 The "sod seeding" technique

The use of heavy machinery and of repeated deep tillage causes several undesired effects, from the agronomic and ecological viewpoint.
These effects are partially due to soil compression, leading to a continual deterioration of fertility.
This situation highlights the need for improving the way the machinery works and the need for soil tillage techniques (conservation techniques).
These techniques combined with others limit the use of machinery and environmental impact.
The technique of "minimum tillage", or of seeding on a no tillage soil (no tillage, direct trilling or sod seeding) are an example of the sod seeding technique. Even though there is a long way to go, these techniques are already employed in several countries, which have either developed or undeveloped agricoltural systems (5).
The first techniques described are soil tillage techniques, with a reduction in the depth of tillage and a reduction operations necessary to create suitable seed beds.
The work of the machines over the ground is also greatly reduced; ploughing is replaced by extirpation, mechanical diggers and milling cutters are used.
'Sod seeding' involves seeding among the stubble of previous cultivation from a seeding machine, equipped with disk furrow openers.
Therefore no soil tillage, ploughing and complementary working is needed (6).
Born in the United States, the "sod seeding" technique quickly spread throughout many countries of South America (particularly Argentina) (7).
It helps prevent the problems of soil erosion (in subarid environments (8) due to extensive monocoltural methods used by the multinational companies of this sector.
Sod seeding is now used in a limited way throughout Italy and Europe, and it is studied and experimented on by the Institutes of Agronomy in Padova, Bologna and Viterbo and by the Institutes of Agrarian Mechanics in Padova, Pisa, Bologna and Milano (9).
Sod seeding is widespread in Northern Italy (Val Padana for maize after winter wheat) and more recently it has been adopted in meridional and Sicilian agriculture, by large farms where the production of cereals prevails.
Sod seeding, which consists of both preparation and seeding soil in a single go, means only part of the soil needs to be seeded.
It has many significant advantages: avoiding the removal of the coltural residue helps the humidifying process and increases the amount of organic substances

(4) The term sustainable agriculture refers to long term cultivation which doesn't drain natural resources for future generations to come, as outlined in the Bundtland Report in 1987. We agree on three determining factors for the development of sustainable farming (Pearce D. and others): the importance the environment, strong future prospects and the concept of fairness regarding our generation and generations to come.
(5) United States, South America, Europe, South Africa and Australia.
(6) Sod seeding is more suitable for winter crop cultivation, cereals, spring cereals, winter colza, maize sunflowers and beetroot.
(7) The total number of hectares used for no tillage is 100,000 approx. and are mainly used for the cultivation of autumn-winter soya and cereals, maize, sunflowers and sorghum (Sartori L., Sandri R., 1996).
(8) The anti-erosion effect of sod seeding is one the main reasons for the interest and wide spread use of this method.
(9) Let's remeber the no tillage techniques were brought to light by the project INNOVA carried out by INEA, the research on the problem of desertification by for INCO-DC 'Desertification in the Mediterranean Drylands: Development of a Monitoring System based on Plant Eco-physyology' (DEMOS) carried out by the Department of Biology of Trieste University (co-ordination), Mediterranean Agronomic Institute of Chania (Greece), Centre of Environmental Studies and Botany Department, Ege University, Bornova Izmir (Turkey), the Faculty of Agricultural Science, Lebanese University, Beirut (Lebanon). Furthermore, we'd like to note 'Progamma Operativo Multiregionale' (Multi-regional Work Programme) dedicated to 'Supporting agricultural development projects' that, at Measure 2, 'Technological innovations and the transferal of research results' is in the process of researching 'Agricultural techniques for working the ground in terms of sustainable farming within the meridional inland hills'. The goal of the project is: 'study, transfer and diffusion of minimum tillage to safeguard the soil, the terrain and looking at the economic benefit for hot-arid mediterranean environments. This project includes studies from Istituto di Agronomia generale e coltivazioni erbacee in Palermo (co-ordination), the Department of Agro-chemistry and Agro-biology of the University of Reggio Calabria, Istituto sperimentale colture industriali (ISCI) in Bologna. This project focuses on Calabria and Sicily.

in the soil ([10]). Therefore the soil becomes more resistant to changes in the soil surface. There is also a mulching effect, which has advantages concerning the control of water evaporation and crust formation.
This technique is interesting because it doesn't damage the structure and integrity of soil, by preventing water loss from the top layers of soil brought to the surface using traditional tillage. Traditional tillage is subject to loss of moisture through evaporation. Therefore no tillage is appropriate for areas of low rainfall, such as most of southern Italy.
This technique also guarantees similar soil porousness to ploughed soils, thanks to a natural porosity ([11]) caused by the action of the earth entomo-fauna (in particular earth-worms) and the growth of plant roots.
Among the positive features, the reduction of labour costs and low consumption of energy, compared to traditional farming machinery, is of great interest ([12]).
Another important advantage is the speed of operations, which is faster thanks to a more simplified work process, which avoids or limits losses due to late seeding ([13]).
The simplification of the work process is linked to another more important economic gain for the farmer who chooses to employ the 'sod seeding techinque'. This is because less farm machinery is needed even though the cost of sod seeding machines is high for the less affluent farms ([14]).
We should note that this technique limits the environmental impact on earth entomo-fauna, which is fundamental for soil fertility. Farm machinery, going over the soil, damages earth fauna. The biodinamic agricultural method reduces damage, by limiting the use of heavy farm machinery.
The problems that came to light in the 80's have almost all been resolved, in particular those concerning seed distribution and the difficulties incumbered due to residue from previous cultivation that clogs machinery. In the first few years of repeated crop there may be problems linked to the presence of weeds. The weeds gradually becomes less in the years to follow. During the initial stages, if necessary disherbants may be used before seeding and if need be chemical products. This comes as a contradiction to the eco-friendly method, with low level environmental impact and the necessity to use traditional chemical methods. However, we must underline the fact that the use of chemicals is careful and limited, thus limiting toxic residue in the soil and cultivation ([15]).
The main problem facing farms is the rising cost of herbicides, necessary in the short term. However, reduced expenditure in terms of farm machinery and equipment makes up for this ([16]).
The difficulty with using the sod seeding technique arises when the soil has been previously cultivated. The growing use of heavy farm machinery on damp soil surfaces compresses the terrain, making it necessary to plough the terrain deeply before sod seeding.
Other problems can arise from waterlogged soil, especially where the ground is not levelled and therefore optimum results cannot be obtained.
As we can see from the results of the survey, up until now profit is good from farms employing 'no tillage' methods, compared to farms using traditional methods. In fact, research ([17]) for autumn-winter cereals shows that 78% of farms have increased profit, for 15% of farms profit has remained the same and only 2% of farms have made a loss.
However, the results are different for maize ([18]) and soya. As far as maize is concerned, 31% of farms have made a loss, just as another 31% have unchanged profit and 25% have increased profit. The results for soya are as follows: 21% of farms have made a loss, 21% of farms have unchanged profit and 37% have increased their profit ([19]).
Other studies ([20]) have compared traditional ploughing methods and the 'no tillage' ([21]) technique in terms of labour time employed, initial set up costs, gross profit and other variable expenses, for durum wheat and spring wheat.
Research has shown that the time needed to set up an alternative type farm is 80% less than that needed to set up a traditional farm. Fuel consumption is reduced from 90% to 75% according to the type of farm machinery employed, with sod seeding machines reducing costs

([10]) The no tillage method has positive results for the fertility of the terrain. In particular, adopting the sod seeding method especially where the ground is impoverished, over a 10 year period the organic content of the soil can be increased (from less than 1% to more than 3%).
However, the use of ploughing on the same kind of soil reduces the quantity of humus (Peruzzi A., 1995).
([11]) The so called 'bio-pores'.
([12]) Large agro-mechanical farms working in contract play an important part in the diffusion of the sod seeding method, because smaller farms have more limited economic resources.
([13]) Looking at the second harvest, late seeding reduces the amount of maize harvested by 0.85% and soya by 1% for every day late (Pergher G., Gubiani G., 1992).
([14]) The machinery for sod seeding is expensive, therefore only suitable for large or working in contract farms. However this is counteracted by the benefits from its versatility. This is because one sod seeding machine replaces the work of other machines, therefore reducing the amount of machinery needed so reducing energy consumption and labour saving.
([15]) Peruzzi A., Sartori L., 1994.
([16]) Considering a use of 150-200 hours, the cost of direct seeding is about 90.000 lira/ha and it is only 23% of the cost of traditional ploughing (Peruzzi A., Di Ciolo S., Frondoni U., 1993).
([17]) Sartori L., Sandri R., 1996.
([18]) It's worth noting that a reduction in the depth of ploughing reduces the amount of maize harvested.
([19]) The research shows that the difference between the sum of the results and 100 is due to a lack of precision.
This amounts to 5% for autumn-winter cereals, 13% for maize and 21% for soya. The sod seeding method seems to be successful for some cultivations across different terrains (especially for straw cereals). However there seem to be some difficulties for the 'mono-stem' precision seeding species (maize, sunflowers, etc.) (Peruzzi A., 1995).
([20]) AA. VV., Terra e Vita, n° 34, 1994.
([21]) For this case, we have used the combine 'Horsch' for direct seeding and two sod seeding machines for the no tillage, 'Sulki' and 'Directa' (Terra e Vita, 1994).

by a further 70%, which enable areas 4 or 5 times greater to be covered in a shorter time.
The use of the sod seeding machines only reduces variable expenses by 20% because of initial costs incurred for weed killing. Gradually weeds disappear as the years go by.
Even if there are losses in production, research has shown that profit levels remain the same due to reduced costs in other areas. Looking at various agricultural ventures, we have noticed that when losses occur they are around 15% for durum wheat and 20% for wheat.
Other research has shown that losses vary from farm to farm in Northern Italy. In some cases farms make a loss on wheat, in other cases there's an increase in profit for wheat and soya ([22]).
Research shows that the sod seeding method is economically viable in certain areas. This depends on differing production processes from farm to farm (wheat, maize, sunflowers, soya, etc.) and different environmental characteristics (paedoclimatics, etc.).
As yet, research is incomplete as it doesn't confirm that the sod seeding method is beneficial to the economy, the environment and society. These benefits are difficult to estimate because of the lack of a concrete method of evaluation. This is due to unknown variables within ecology and bio-agronomy. Social and economic variables are linked to the future development of some areas which seriously risk degradation.

2. The employment of alternative methods of conservation and their economic advantages in Sicily

2.1 The sod seeding method in Sicily

Durum wheat cultivation in Sicily covers an area of 365000 hectares, which is 22% of the total cultivation in Italy. Over the last thirty years the terrain employed for durum wheat cultivation in Sicily has been greatly reduced. A comparison of the data shows that in 1968 approx. 595000 hectares were employed, whereas in 1998 only 322000 hectares were employed. Therefore there has been a reduction of 46% of the total area used for production of durum wheat. This result is mainly due to a change in production in flat areas.
On the contrary, durum wheat production has remained unchanged since1968. This is because of the introduction of more productive varieties of durum wheat and techniques of intensive production, which has counterbalanced the decrease in the amount of area cultivated.
The ISTAT information from 1998 shows production to be approx. 80 tons of durum wheat in Sicily which represents approx. 17% of national production (approx. 480,000 tons).
Most of the durum wheat is cultivated primarily around Palermo and also, in order of importance, Caltanissetta, Enna, Agrigento and Catania. Together they make up 83% of the total area used for durum wheat cultivation in Sicily.
As previously mentioned, intensive traditional methods of monocoltural farming may cause a reduction of humus in the soil, causing the ground to become unstable. Looking at Sicily, in recent years desertification has become a problem in certain areas on the island. This is due to a combination of factors, both natural and social. In south-eastern Sicily, the change in climate and increased economical activity have accelerated the process of desertification.
The use of 'minimum tillage' and direct seeding helps to resolve this problem as well as other social and economic problems linked to the cultivation of cereals. (If we look at the work, both manual and machine powered, working 1 hectar of terrain over 22 hours, creates job opportunities for a million working days per year. If cultivation discontinues, this creates great problems of unemployment).
The increase in cost of production in recent years and the decrease in market prices have caused a slump in the market for durum wheat. In areas where production is below 2.5 tons/ha, earnings from sales (net of European community support) are below the cost of production.
An important feature for future cereal cultivation in Sicily is the opportunity to limit cost of production for farms. At present, farms are paralyzed by the high cost of durum wheat production. This particularly affects farms inland, which still mainly use traditional farming methods.
The areas covered by the farm survey are mainly clay and have an average rainfall of 450-500 mm/year, mainly use monocoltural methods in the production of cereals (durum wheat) or cereal fodder, and are found inland in the hills around Palermo and Caltanissetta.
These farms are low earners, they employ simple methods, with a high energy input and consequently have a great impact on the environment, which causes paedologic degradation. In these areas, the average yearly rainfall (calculated every 20 years) is between 475 mm and 498 mm ([23]), which is the same as average rainfall in cereal growing areas in central Sicily.

2.2 Case studies

The following results are from surveys carried out on 4 Sicilian farms which produce cereals (durum wheat). Three of these farms employ 'no tillage' methods and one of them uses traditional methods. All farms are found in the same territorial area.
As the sod seeding method is not widespread, our surveys have been carried out only on farms which have been employing this 'philosophy' of production for sev-

([22]) Toni B., 'Semina diretta: i risultati dal Nord al Sud', Coltivare Conservando, Edagricole, 1993.
([23]) In particular, the first measure comes from the survey station in Alia, near palermo, and the second comes from the survey station in Chibbò - Marianopoli, near Caltanissetta.

eral years. These farms have a large store of machinery and good organisation.
We have surveyed 3 farms, 2 near Palermo and 1 near Caltanissetta, looking at 'no tillage' and 'minimum tillage'. The first 2 farms are found in the Roccapalumba and Alia territories, the third in Marianopoli.
We have compared the findings with a 4th close by farm (in Sclafani Bagni), which employs traditional methods: ploughing and harrowing. All farms produce cereals, particularly durum wheat. Rotating cultivation used by these farms is as follows: wheat, wheat or other cereals (barley or oats), leguminosae annuals (vetch, clover, fava bean, etc.).
We have surveyed areas of similar terrain for each farm; all three farms have been using the 'no tillage' method for more than five years, replacing traditional methods in all rotating cultivations. Each farm has seeded 180 kg/ha of durum wheat (Farm 1: Simeto, Farm 2: Ciccio, Farm 3: Duilio/Arcangelo, Farm 4: Simeto). Farm 1 used 0.1 t/ha of manure containing 46% agricultural urea and the remaining farms have fertilised 0.35 t/ha with entec 25/15 using slow release nitrogen.
Wheat production varied as follows: 4 t/ha for farm 1, 3 t/ha for farm 2, 3.8 for farm 3 and 3.4 for farm 4.
The sod seeding method includes the following operations: soil remains unploughed after harvest; subsequently, around October time, when rainfall causes the growth of weeds, weeds are destroyed using glifosate (an active substance) in order to prepare the soil for the new seeding. In November it's time to sow the seeds, using sod seeding machines on unploughed soil.
In October and/or November, after the harvest, the 'minimum tillage' method involves one or two goes of the harrow, instead of using chemical herbicides.
After summer ploughing, the traditional method involves one or two goes of the harrow (with disks or flexible teeth, depending on how turfy the soil is) after the first autumn rainfalls and after seeding towards the end of autumn.
It's worth underlining that we calculate these values referring to durum wheat cultivation and that we consider as parameters the cost of mechanical labour, herbicides, labour time and energy consumption.
The comparison of the farms has shown the advantages of the 'no tillage' methods. We have found that using this method of farming levels of production are the same as those obtained by using traditional farming techniques. Farms have also reduced their expenses and have been more timely in the various operations of cultivation.
The 3 farms which employed conservation methods have used very different equipment and machinery for sod seeding.
Farm 1 (in Roccapalumba territory) has a 'Case International 73 kw' tractor and an 'Amazzone' sowing-machine; Farm 2 (Alia) has a 'John Deere 3350 73 kw' tractor and a 'F.lli Calà' sowing-machine with hoe furrow operners; Farm 3 (Marianopoli) has a 'John Deere 95 Kw' tractor and a 'John Deere' sowing-machine con disk furrow openers. The last machine is more expensive than the others because of its technical features. It guarantees perfect seeding even over hard and unploughed terrains. Its disks work in perfect synchronism in order to glide over the ground and scatter seeds accurately. Instead, the 'Amazzone' sowing-machine has spaded furrow openers which can be get clogged up by weeds, wasting time. The 'John Deere' sowing-machine has high maintenance costs because its disks can be more easily damaged than its spaded.
Different factors affect the choice of equipment and tractors. Farm 1 bought the 'Amazzone' sowing-machine because of the good price offered by the producer (SAVE); farm 2 bought the 'Calà' sowing-machine because of the relationship between the amount of terrain/cost of the machine made it economical; farm 3 employed a 'John Deere' sowing-machine because the farmer himself sells the machines. Farm 4 bought a 'Fiat 58.5 Kw' tractor with tracks, a 'Nardi 2BT' ploughshare, a harrow with flexible teeths with 11 points and a vibrotiller with 3 meters springs. For seeding, this last farm also employes a centrifugal fertilizer distributor. Seeds are covered by a vibrotiller.
After completing the survey and compiling the technical data, we worked on the economic analysis, calculating the possible benefits of sod seeding and of 'minumum tillage' compared to the benefits form traditional methods of cultivation on Farm 4 (in Sclafani Bagni territory). We have taken into account the following parameters: labour time needed for total operations, fuel consumption and total cost of cultivations.
As to the level of activity per hectare, in the first 3 farms, employing the 'no tillage' method there has been a reduction of 2.8 labour hours per cultivated hectare and of 2 labour hours when employing the 'minumum tillage' method (**Tab. 1**). As to the fuel consumption, there has

Table 1 ***Employment of mechanical labour in the different techniques (h/Ha).***

Operations	Farm 1 Sod seeding	Farm 2 Minimum tillage	Farm 3 Sod seeding	Farm 4 Traditional
Ploughing	—	—	—	2.5
Harrowing	—	1.3	—	1.3
Manuring	1.0	1.0	1.0	1.0
Seeding	1.5	1.5	1.5	1.0
Weed killing	1.0	0.5	1.0	0.5
Harvest	1.0	1.0	1.0	1.0
Total	**4.5**	**5.3**	**4.5**	**7.3**

Table 2 ***Fuel consumption in the different working techniques (kg/Ha).***

Operations	Farm 1 Sod seeding	Farm 2 Minimum tillage	Farm 3 Sod seeding	Farm 4 Traditional
Ploughing	—	—	—	31.0
Harrowing	—	8.5	—	8.5
Manuring	3.0	3.0	3.0	3.0
Seeding	3.0	3.0	3.0	1.5
Weed killing	3.0	1.5	3.0	1.5
Harvest	3.5	3.5	3.5	3.5
Total	**12.5**	**19.5**	**12.5**	**49.0**

Table 3 ***Total labour costs of the different techniques.***

Calculation parameters	Farm 1 Sod seeding	Farm 2 Minimum tillage	Farm 3 Sod seeding	Farm 4 Traditional
Value of new machinery	177,000,000	146,000,000	198,500,000	120,000,000
Invariable expenses:				
Depreciation	16,150,000	13,450,000	18,137,500	11,250,000
Interests on capital employed for machines	3,650,000	2,900,000	5,950,000	2,050,000
General expenses	730,000	580,000	1,190,000	410,000
Maintenance	9,380,000	7,840,000	10,540,000	6,600,000
Insurance	120,000	100,000	150,000	100,000
Total invariable expenses (2/3)	**10,010,000**	**8,290,000**	**11,989,166**	**6,803,333**
Invariable expenses/Ha	333,666	276,333	399,639	226,778
Variable expenses:				
Fuel	412,500	643,500	412,500	1,617,000
Lubrificant	162,000	190,800	162,000	262,800
Salaries	1,755,000	2,067,000	1,755,000	2,847,000
Various expenses	810,000		810,000	
Interests on the employed capital	156,975	145,065	156,975	236,340
Total variable expenses	3,296,475	3,046,365	3,296,475	4,963,140
Variable expenses/Ha	109,882	101,545	109,882	165,438
Annual total cost	**13,306,475**	**11,336,365**	**15,285,641**	**11,766,473**
Annual total cost/Ha	**443,549**	**377,879**	**509,521**	**392,216**

been a reduction of 36.5 kg per hectare when employing the 'no tillage' method and of 29.5 kg when employing the 'minimum tillage' method. In order to calculate total costs, we have taken into account the invariable costs (depreciation, insurance, general expenses and interests on machinery capital). We have added variable costs (maintenance, fuel and lubrificants, manual labour and interest on capital employed) to invariable costs. As far as depreciation is concerned, we have taken into account the value of new machinery and equipment, respectively calculated as 10% and 7.5% of capital employed. We have calculated also 5% of annual rates of the present value of the machines. Our estimated insurance share was exactly what the farmers payed for tractors. For general expenses we have calculated an aliquote of 1% of the present value of the machines. In our opinion, this aliquote has been accurately calculated. The attribution of invariable costs has been reduced by 2/3 according to the area cultivated annually with durum wheat, taking into account that the machinery is used throughout the farms (each farm covering an area of 90 hectares).

Among the variable costs (amounts vary proportionally according to the amount of use the machine undergoes), the maintenance of machinery (depending on machine use) has been calculated using an aliquote of 6% of the value of new tractors and 4% for other farm equipment. The expenses for fuel have been calculated on the basis of consumption monitored during cultivation and multiplied by its market price (1,100 lira/kg). The expenses for lubrificants have been calculated considering a possible consumption of 200 g per hour at a price of 13,000 lira per hour, social security benefits included. The acquisition of herbicides used before seeding has been attributed to expenses and has only been calculated for the farms which employ the sod seeding method.

An aliquote of 5% has been used in order to calculate the interest on capital employed.

It's worth underlining that the 30% increase in the price of gas oil over the last agricultural year will have largely affected total variable expenses.

Adding the invariable and variable costs together, it is possible to calculate the total cost of working places. This varies from 377,000 lira per hectare in Farm 2 to 509,000 lira in Farm 3 (Farm 4 remains unchanged at approx. 392,000 lira per hectare).

Variable costs have been lower for the farms employing non-traditional methods. Unvariable costs have been

lower for farm 4 using the traditional method. This is due to high depreciation costs, caused by the high prices of sod seeding machines.
Subsequently, we have calculated the points of indifference, in order to estimate the minimum area for the employment of non-traditional methods and the expenses for machinery. A comparison has been made with farm 4 which employs traditional methods.
Comparing Farm 1 and Farm 4, the point of indifference is an area of 57.72 hectares; comparing Farm 2 and Farm 4 it is of 23.27 hectares; comparing Farm 3 and Farm 4 it is of 93.35 hectares (**Table 4**).
Therefore, the minimum level of an area of durum wheat cultivation is different for the different farms. For those which employ more expensive sowing-machines, the minimum level is more than 50 hectares (Farm 1), and it is close to 100 hectares for Farm 3, which employes a 'John Deere' sowing-machine.
Thus, this technique is suitable for large farms or for associations of producers who may share machinery expenses.

Conclusions

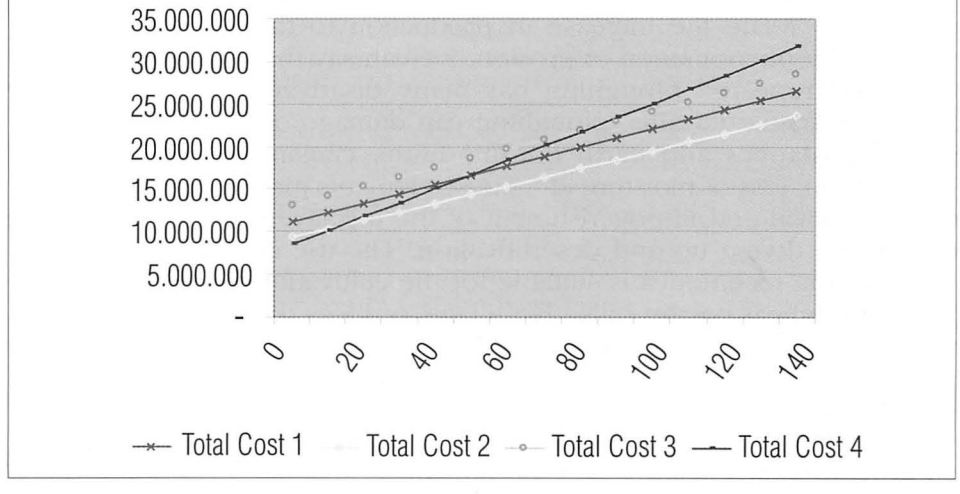
Agrarian soil is a fundamental component of the agricultural environment. It can condition the productivity of plants and influence the dynamics of the natural process. Due to the 'multi-functional' features that agriculture is progressively acquiring, it is necessary to make new goals for technological developmment. The farm cannot be considered as a single productive unity anymore: it has become a fundamental element to manage rural areas. Technical and economic management of farms must be linked to safeguarding the environment, within a 'new' development project aiming for the sustainable management of natural resources. Farm products must be of a high quality (good quality products, good quality foodstuffs, efficient selling and

Table 4 ***Points of indifference per farm.***

	Farm 1	Farm 2	Farm 3	Farm 4
Ha	**30**	**30**	**30**	**30**
Value of new machinery	**177.000.000**	**146.000.000**	**198.500.000**	**120.000.000**
Invariable expenses				
Depreciation	16.150.000	13.450.000	18.137.500	11.250.000
Interests on capital employed for machines	3.650.000	2.900.000	5.950.000	2.050.000
General expenses	730.000	580.000	1.190.000	410.000
Maintenance	120.000	100.000	150.000	100.000
Insurance	9.380.000	7.840.000	10.540.000	6.600.000
Total IE	**10.010.000**	**8.290.000**	**11.989.167**	**6.803.333**
Variable expenses				
Various expenses	810.000		810.000	
Fuel	412.500	643.500	412.500	1.617.000
Lubrificant	162.000	190.800	162.000	262.800
Salaries	1.755.000	2.067.000	1.755.000	2.847.000
Interests on the employed capital	156.975	145.065	156.975	236.340
Total VE	**3.296.475**	**3.046.365**	**3.296.475**	**4.963.140**
Hours/year	**135**	**159**	**135**	**219**
VE year/Ha	**109.883**	**101.546**	**109.883**	**165.438**
Total cost per year	**13.306.475**	**11.336.365**	**15.285.642**	**11.766.473**
Total cost per year/Ha	**443.549**	**377.879**	**509.521**	**392.216**

Hectares	Farms			
0	**Total Cost 1**	**Total Cost 2**	**Total Cost 3**	**Total Cost 4**
10	11.108.825	9.305.455	13.087.992	8.457.713
20	12.207.650	10.320.910	14.186.817	10.112.093
30	13.306.475	11.336.365	15.285.642	11.766.473
40	14.405.300	12.351.820	16.384.467	13.420.853
50	15.504.125	13.367.275	17.483.292	15.075.233
60	16.602.950	14.382.730	18.582.117	16.729.613
70	17.701.775	15.398.185	19.680.942	18.383.993
80	18.800.600	16.413.640	20.779.767	20.038.373
90	19.899.425	17.429.095	21.878.592	21.692.753
100	20.998.250	18.444.550	22.977.417	23.347.133
110	22.097.075	19.460.005	24.076.242	25.001.513
120	23.195.900	20.475.460	25.175.067	26.655.893
130	24.294.725	21.490.915	26.273.892	28.310.273
140	25.393.550	22.506.370	27.372.717	29.964.653
150	26.492.375	23.521.825	28.471.542	31.619.033

Points of indifference = (IEx-IExx)/(VExx-VEx)
Farm 1/Farm 4 57,72
Farm 2/Farm 4 23,27
Farm 3/Farm 4 93,35



production processes and a sustainable use of natural resources). Technological progress, through new sustainable technologies, is the central element for the development of new models of agriculture. These models must be compatible with the new trend in the agro-environmental policy of the European community and safegard world natural resources. The role of scientific research in innovating technology is very important, particularly where new technologies are able to combine economic efficiency of production (benefits for farms and advantages for farmers) and good results in the management of natural resources. This trend may have long term indirect advantages (of a social kind) and may be useful in the market within the short term (quality certification of products, etc.).
In this context, techniques of conservation, particularly sod seeding, may offer new opportunities for modern development in agriculture, i.e. sustainable. This is true both for cereal and durum wheat production, particularly in Sicily.
The problems of erosion, the paedologic, climatic and economic features of the areas cultivated with wheat on the island (and their importance from an agricultural, environmental, social and cultural viewpoint, particularly in inland Sicily) offer interesting opportunities for thinking about the diffusion of new techniques, which are linked to the reduction of seeding costs through sod seeding and 'minimum tillage' methods.
Even if earnings are the feature which mainly influences the choice for using sod seeding, the concept of conservation in terms of the working terrain must be considered as a 'group' of coltural procedures, developed not only aiming to increase earnings but also to preserve the bio-agronomic and ecological features of the soil, safeguarding the territory. It's worth underlining that, in order to guarantee profit to farmers, sod seeding or 'minimum tillage' must be carefully estimated and calibrated. It is necessary to use the most suitable techniques and best equipment for each environmental context. Though in some cases it is not possible to relate the increase in production to the trend of the phenomenon of erosion, we can say that deep and repeated ploughing has many disadvantages. On fragile terrains, ploughing can damage organic substances and earth entomo-fauna causing degradation, loss of moisture etc. These elements may cause removal and impoverishment of the top layers of the soil, drying up and desertification. The use of conservation techniques is suitable for the cultivation of durum wheat on the hills. 'No tillage' reduces the risk of erosion. This environment, inland hilly Sicily, is problematic because much of its agriculture is dying out, due to soil erosion and desertification. This is also a problem near Ragusa and Siracusa. For the farm, another important feature is the reduction of manual labour and the simplification of machinery and cyclical labour, which makes the farm easier to manage. Indirect benefits are many: the possibility of supporting rural populations (an incentive for new settlement), the possibility to preserve the hydro-geological features of the territory in order to safeguard the environment (Sicilian inlands).
To conclude, it's worth underlining the difficulty in employing and diffusing new techniques throughout the areas where Sicilian durum wheat is cultivated. The main obstacle faced by farms is the high initial investment for equipment. This means that only larger farms (over 100 Ha) can benefit from the acquisition of machinery. Smaller farms must find an alternative, such acquiring machinery through forming associations of producers or renting. For the latter, we think that the present structure of work in contract in Sicily doesn't permit immediate development of sod seeding techniques.
For this reason, we hope that the farms which work in contract can be re-organised thanks to the input from the 'Sections of Technical Assistance of Regione Siciliana' and from incentives given for the acquisition of machinery and equipment, which help diffuse the sod seeding technique. ●

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