**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.

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**INTRODUCTION**

The diffusion of intensive monocultural systems, based on the wide spread use of chemical substances (such as fertilizers, pesticides, herbicides) and on heavy mechanisation, 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 (*) and following. This research deals with aspects of mechanisation, 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 mechanisation 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 (**).

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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 (**). 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-
mote European community incentives to buy machinery.
We must remember that until the 1992 reform the trend in Community Agricultural politics privileged the quanti-
titative aspects of production, focusing less on looking at
the merits of mechanization, we must take into ac-
count that there is still room for improvement.
As far as sustainable agriculture is concerned, one im-
provement 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 farm-
ing 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 in-
volves the removal of woods, hedgerows and meadow-
s. These areas are vital to birds, insects, rodents, etc.
The use of machinery hinders normal biological regen-
eration of the soil, deteriorates its quality and causes
compression, which leads to soil erosion and in time ru-
ins the rural landscape.
At present, the organisation of farms requires an ex-
tended use of agro-mechanical machinery, we mustn't
forget the impact this has on the environment.
Today, the European Community safeguards the envi-
ronment 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 ecosys-
tem.

Sod seeding, used in Italy for autumn-winter cereal cul-
tivations (second seeding for maize), is a good example
of alternative sustainable agriculture (1).

1.1 The “sod seeding” technique

The use of heavy machinery and of repeated deep
tillage causes several undesired effects, from the agro-
nomic 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 tech-
niques (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 ei-
er developed or undeveloped agricultural systems (2).
The first techniques described are soil tillage tech-
niques, with a reduction in the depth of tillage and a re-
duction operations necessary to create suitable seed
beds.
The work of the machines over the ground is also great-
ly reduced; ploughing is replaced by extirpation, me-
chanical 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 (3).

Born in the United States, the “sod seeding” technique
quickly spread throughout many countries of South
America (particularly Argentina (4)).
It helps prevent the problems of soil erosion (in sub-
arid environments (4) due to extensive monocultural
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 (5).
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 agricul-
ture, 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 re-
moval of the cultural residue helps the humidifying
process and increases the amount of organic substances

(1) The term sustainable agriculture refers to long term cultivation which does-
'tn't drain natural resources for future generations to come, as outlined in the
Bundlstand Report in 1987. We agree on three determining factors for the de-
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.
(2) United States, South America, Europe, South Africa and Australia.
(3) Sod seeding is more suitable for winter crop cultivation, cereals, spring
cereals, winter colza, maize sunflowers and beetroot.
(4) 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, mai-
ze, sunflowers and sorghum (Santori L., Sandri R., 1996).
(5) The anti-erosion effect of sod seeding is one the main reasons for the in-
terest and wide spread use of this method.
(6) Let's remember the no tillage techniques were brought to light by the
project INNOVA carried out by INEA, the research on the problem of deser-
tification by for INCO-DC 'Desertification in the Mediterranean Drylands: De-
velopment of a Monitoring System based on Plant Eco-physiology' (DEMOs)
carried out by the Department of Biology of Trieste University (co-ordina-
tion), Mediterranean Agronomic Institute of Chania (Greece), Centre of En-
vironmental Studies and Botany Department, Ege University, Bornova Izmir
(Turkey), the Faculty of Agricultural Science, Lebanese University, Beirut (Le-
banon). Furthermore, we'd like to note 'Programma Operativo Multiregiona-
le' (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 te-
chniques for working the ground in terms of sustainable farming within the
meridional inland hills'. The goal of the project is: ‘study, transfer and diffu-
sion of minimum tillage to safeguard the soil, the terrain and looking at the
economic benefit for hot-arid mediterranean environments. This project in-
cludes studies from Istituto di Agronomia generale e coltivazioni erbacee in
Palermo (co-ordination), the Department of Agro-chemistry and Agro-bio-
logy of the University of Reggio Calabria, Istituto sperimentale colture indu-
striali (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 porosity 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 technique'. 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 surface 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
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 vari­
able 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 ven­
tures, 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 econom­
ically viable in certain areas. This depends on differing
production processes from farm to farm (wheat, maize,
sunflowers, soya, etc.) and different environmental char­
acteristics (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 vari­
ables 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 greatly re­
duced. A comparison of the data shows that in 1968 ap­
prox. 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 introduc­
tion of more productive varieties of durum wheat and
techniques of intensive production, which has counter­
balanced 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 rep­
resents 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 monocultural farming may cause a reduction of hu­
mus in the soil, causing the ground to become unstable.
Looking at Sicily, in recent years desertification has be­
come 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 in­
creased 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 eco­
nomic problems linked to the cultivation of cereals. (If
we look at the work, both manual and machine pow­
ered, working 1 hectare 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 Sici­
ly is the opportunity to limit cost of production for farms.
At present, farms are paralyzed by the high cost of du­
rum wheat production. This particularly affects farms in­
land, 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, main­
ly use monocultural methods in the production of cere­
als (durum wheat) or cereal fodder, and are found inland
in the hills around Palermo and Caltanissetta.
These farms are low earners, they employ simple meth­
ods, with a high energy input and consequently have a
great impact on the environment, which causes paedo­
logic degradation. In these areas, the average yearly rain­
fall (calculated every 20 years) is between 475 mm and
498 mm (23), which is the same as average rainfall in ce­
real 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 sur­
veys have been carried out only on farms which have
been employing this 'philosophy' of production for sev­
erel 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 Bagnti), 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, farva 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: Duiillo/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 seed sowing 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 Internazionale’ tractor and an ‘Amazzone’ sowing-machine; Farm 2 (Alia) has a ‘John Deere’ 3350 73 kw’ tractor and a ‘Flli Calà’ sowing-machine with hoe furrow openers; 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 teeth with 11 points and a vibrotiller with 3 meters springs. For seeding, this last farm also employs 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 ‘minimum tillage’ compared to the benefits form traditional methods of cultivation on Farm 4 (in Sclafani Bagnti 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 ‘minimum tillage’ method (Tab. 1). As to the fuel consumption, there has

<table>
<thead>
<tr>
<th>Operations</th>
<th>Farm 1 Sod seeding</th>
<th>Farm 2 Minimum tillage</th>
<th>Farm 3 Sod seeding</th>
<th>Farm 4 Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2.5</td>
</tr>
<tr>
<td>Harrowing</td>
<td>—</td>
<td>1.3</td>
<td>—</td>
<td>1.3</td>
</tr>
<tr>
<td>Manuring</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Seeding</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Weed killing</td>
<td>1.0</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Harvest</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.5</strong></td>
<td><strong>5.3</strong></td>
<td><strong>4.5</strong></td>
<td><strong>7.3</strong></td>
</tr>
</tbody>
</table>
Table 2 Fuel consumption in the different working techniques (kg/Ha).

<table>
<thead>
<tr>
<th>Operations</th>
<th>Farm 1 Sod seeding</th>
<th>Farm 2 Minimum tillage</th>
<th>Farm 3 Sod seeding</th>
<th>Farm 4 Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>31.0</td>
</tr>
<tr>
<td>Harrowing</td>
<td>—</td>
<td>8.5</td>
<td>—</td>
<td>8.5</td>
</tr>
<tr>
<td>Manuring</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Seeding</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Weed Killing</td>
<td>3.0</td>
<td>1.5</td>
<td>3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Harvest</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12.5</td>
<td>19.5</td>
<td>12.5</td>
<td>49.0</td>
</tr>
</tbody>
</table>

Table 3 Total labour costs of the different techniques.

<table>
<thead>
<tr>
<th>Calculation parameters</th>
<th>Farm 1 Sod seeding</th>
<th>Farm 2 Minimum tillage</th>
<th>Farm 3 Sod seeding</th>
<th>Farm 4 Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of new machinery</td>
<td>177,000,000</td>
<td>146,000,000</td>
<td>195,500,000</td>
<td>120,000,000</td>
</tr>
<tr>
<td><strong>Invariable expenses:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>16,150,000</td>
<td>13,450,000</td>
<td>18,137,500</td>
<td>11,250,000</td>
</tr>
<tr>
<td>Interests on capital employed for machines</td>
<td>3,650,000</td>
<td>2,900,000</td>
<td>5,950,000</td>
<td>2,050,000</td>
</tr>
<tr>
<td>General expenses</td>
<td>730,000</td>
<td>580,000</td>
<td>1,190,000</td>
<td>410,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>9,380,000</td>
<td>7,840,000</td>
<td>10,540,000</td>
<td>6,600,000</td>
</tr>
<tr>
<td>Insurance</td>
<td>120,000</td>
<td>100,000</td>
<td>150,000</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total invariable expenses (2/3)</strong></td>
<td>10,010,000</td>
<td>8,290,000</td>
<td>11,989,166</td>
<td>6,883,333</td>
</tr>
<tr>
<td><strong>Invariable expenses/Ha</strong></td>
<td>333,666</td>
<td>276,333</td>
<td>399,639</td>
<td>226,778</td>
</tr>
<tr>
<td><strong>Variable expenses:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>412,500</td>
<td>643,500</td>
<td>412,500</td>
<td>1,617,000</td>
</tr>
<tr>
<td>Lubricant</td>
<td>162,000</td>
<td>190,800</td>
<td>162,000</td>
<td>262,800</td>
</tr>
<tr>
<td>Salaries</td>
<td>1,755,000</td>
<td>2,067,000</td>
<td>1,755,000</td>
<td>2,847,000</td>
</tr>
<tr>
<td>Various expenses</td>
<td>810,000</td>
<td>810,000</td>
<td>810,000</td>
<td>810,000</td>
</tr>
<tr>
<td>Interests on the employed capital</td>
<td>156,975</td>
<td>145,065</td>
<td>156,975</td>
<td>236,340</td>
</tr>
<tr>
<td><strong>Total variable expenses</strong></td>
<td>3,296,475</td>
<td>3,046,365</td>
<td>3,296,475</td>
<td>4,963,140</td>
</tr>
<tr>
<td><strong>Variable expenses/Ha</strong></td>
<td>109,882</td>
<td>101,545</td>
<td>109,882</td>
<td>165,438</td>
</tr>
<tr>
<td><strong>Annual total cost</strong></td>
<td>13,306,475</td>
<td>11,336,365</td>
<td>15,285,641</td>
<td>11,766,473</td>
</tr>
<tr>
<td><strong>Annual total cost/Ha</strong></td>
<td>443,549</td>
<td>377,879</td>
<td>509,521</td>
<td>392,216</td>
</tr>
</tbody>
</table>

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 lubricants, 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 lubricants 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 employs 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 development. 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 marketing, etc.).

### Table 4 Points of indifference per farm.

<table>
<thead>
<tr>
<th>Hectares</th>
<th>Farm 1</th>
<th>Farm 2</th>
<th>Farm 3</th>
<th>Farm 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Total Cost 1</td>
<td>Total Cost 2</td>
<td>Total Cost 3</td>
<td>Total Cost 4</td>
</tr>
<tr>
<td>20</td>
<td>12.207.650</td>
<td>10.320.910</td>
<td>14.186.817</td>
<td>10.112.093</td>
</tr>
<tr>
<td>30</td>
<td>13.306.475</td>
<td>11.536.365</td>
<td>15.255.642</td>
<td>11.766.473</td>
</tr>
<tr>
<td>50</td>
<td>15.504.125</td>
<td>13.367.275</td>
<td>17.483.292</td>
<td>15.075.233</td>
</tr>
<tr>
<td>60</td>
<td>16.602.950</td>
<td>14.387.730</td>
<td>18.582.117</td>
<td>16.729.615</td>
</tr>
<tr>
<td>70</td>
<td>17.701.775</td>
<td>15.398.185</td>
<td>19.680.942</td>
<td>18.383.985</td>
</tr>
<tr>
<td>80</td>
<td>18.800.600</td>
<td>16.413.640</td>
<td>20.779.767</td>
<td>20.038.373</td>
</tr>
<tr>
<td>100</td>
<td>20.788.250</td>
<td>18.444.550</td>
<td>22.977.417</td>
<td>23.547.133</td>
</tr>
<tr>
<td>110</td>
<td>21.576.075</td>
<td>19.460.005</td>
<td>24.076.242</td>
<td>25.001.515</td>
</tr>
<tr>
<td>120</td>
<td>22.363.900</td>
<td>20.475.460</td>
<td>25.175.067</td>
<td>26.655.895</td>
</tr>
<tr>
<td>140</td>
<td>23.939.550</td>
<td>22.506.370</td>
<td>27.372.717</td>
<td>29.964.653</td>
</tr>
</tbody>
</table>

### Points of indifference = (IE1-Exc) / (VE1-Exc)

- Farm 1/Farm 4 = 57.72
- Farm 2/Farm 4 = 23.27
- Farm 3/Farm 4 = 93.35

![Graph representing the points of indifference](image-url)
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 safeguard 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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