"Life Cycle Assessment (LCA) as a Decision Support Tool (DST) for the eco-production of olive oil"

TASK 4.3

Guidelines for the eco-production of olive oil

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Policy document for the improvement of the olive oil production cycle

The olive cultivation stage

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Financial support from the EC financial instrument for the environment

LIFE-Environment

Chania, 2006

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1 Introduction

This project aims at developing a decision support tool (DST) for the adoption of the appropriate processes throughout the life cycle of olive oil, in order to promote its eco-efficient production in three major olive oil producing areas: Voukolies (Greece), Lythrodontas (Cyprus) and Teruel (Spain). This aim will be achieved through Life Cycle Analysis, a technique for assessing the environmental aspects and potential impacts associated with a product over its life cycle.

The preceding three tasks of this project recorded and assessed the existing situation in regards to relevant legislation, current agricultural practices as well as the wider use of the LCA technique. They also identified the major sources of pollution throughout the whole lifecycle of the production of the olive oil.

The aim of this report is, based on the results of the previous tasks, to develop guidelines for the eco-production of olive oil, for all stages involved in this process. These guidelines will be communicated to the olive and olive oil producers in the regions under examination, in order to make a first step towards the improvement of the environmental performance of the actors involved in the olive oil production cycle.

The report focuses on the cultivation of olives in the farms. A separate report is prepared referring to guidelines for the production of olive oil in the mills.

The guidelines presented in this report derive from the conclusions the working team came up with from the implementation of the LCA in the three areas under examination as well as the experiences and research of the working team in the specific regions

The first section provides a brief description of the main environmental pressures related to the cultivation olives, based on the results of Task 3. These pressures include emissions to air, water and soils, as well as the consumption of energy and water.

Then the guidelines are presented addressing these environmental pressures and including techniques, which improve the environmental conditions related to the oil production. These guidelines refer to the pressures to all the environmental media as well as to the effective use of energy and water.

Finally a policy document giving recommendation for the promotion of the implementation of the guidelines is provided explaining the specific actions that need to be taken mainly by the central authorities in order to give motives for the development of environmentally sound olive oil production systems.

2 Environmental effects of olive farming

Olive farming sector presents significant variations within the various countries. These variations could be categorizes as follows:

- Characteristics of plantation
- Characteristics of farming practices that are applied
- Conditions and characteristics in which the olive farming takes place.
- Socio-economic characteristics of the area and of the farmers

The following are considered the main categories of actual and potential environmental effects associated with the management of olive plantations:

- Soil
- Water
- Air
- Biodiversity (flora and fauna)
- Landscape
- Other effects

2.1 Soil

Soil erosion is reported as one of the main environmental problems associated with olive farming. Soil erosion has various environmental impacts, notably the loss of productive capacity, leading to the need for increased external inputs and ultimately to desertification; and the down-stream effects of run-off, as topsoil, fertiliser and herbicides are washed into water courses and water bodies.

Soil erosion results from a combination of soil type, slope, rainfall patterns and inappropriate farming practices. Intensive tillage not only exposes the soil to the erosive effects of rainfall, it also increases the soil's vulnerability by reducing its organic content, especially when combined with the use of non-organic fertilisers and residual herbicides. The decline in the organic matter content of many soils in southern Europe, as a result of intensive cultivation practices, has become a major process of land degradation.

In many cases, extensive hill areas are cultivated with olives on shallow soils, which are very sensitive to erosion. These areas become especially vulnerable to erosion for two main reasons. First, because of the inadequate protection with vegetation due to intensive cultivation. Second, due to the reduction of infiltration rates which follows the compaction from farm machinery and the formation of soil surface crust.

Widespread olive production in semi-mountainous and mountainous areas of Greece, in combination with the natural lack of water and with excessive grazing pressure, has resulted in desertification problems in semi arid areas, for example in Central and East Crete.

Also, large areas of land have been cleared in recent years for new olive plantations and are subsequently eroded by gullies. Soil erosion is also caused in some areas when intensive goat and sheep grazing follows the abandonment of olive cultivation.

2.2 Water

2.2.1 Controlling run-off in upland areas

Olive plantations on terraces (and their associated channels and ditches) in upland areas can help to slow run-off and improve water penetration, thus reducing the risk of floods in lowland areas following heavy periods of rainfall.

2.2.2 Run-off to surface waters of soil, fertilisers and pesticides

The pollution of surface waters by fertilisers and pesticides is an important consequence of soil erosion caused by olive cultivation. Soil run-off into reservoirs also leads to important economic costs, since the water of dams and other water recipients is polluted and becomes improper for using (water used for irrigation or for the production of potable water).

Where residual herbicides are used widely and intensively, large quantities are washed into streams, rivers and reservoirs with the soil that is eroded.

2.2.3 Pollution of ground water

Excessive applications of nitrogen fertilisers in continuous cultivation without cover cropping can lead to nitrogen leaching. Nitrogen leaching may pollute surface and groundwater with hazardous compounds. Excess of potassium and phosphorus fertilisers contaminates also the soil with these macro-nutrients. This contamination may create nutrient deficiencies in olive trees and even leaching of these nutrients to surface and groundwater. Soil and water can be contaminated by the random uses and the overdoses of synthetic fertilisers and other agrochemicals.

2.2.4 Exploitation of ground and surface waters for irrigation

Although drip irrigation is the most widespread system of irrigation in olive plantations and the quantities used per hectare are relatively low compared with arable cropping, irrigated olive plantations cover an increasingly large area in some regions are their total impact on water resources is considerable. The regions concerned often have serious water deficit problems.

Irrigated olive plantations have continued to expand even though ground waters are severely depleted. There appear to be insufficient mechanisms to ensure that irrigation does not exceed the sustainable capacity of water resources.

Deep wells and irrigation has been installed in many areas especially in plains and their surrounding hills, which has converted what used to be dry cultivation of olive trees to drip-irrigated cultivation. The rise in productivity in olive groves has been achieved at the cost of a dramatic reduction in the groundwater level in many cases, as there is no effective control on the amount of water which is extracted.

2.3 Air

No concrete data were reported concerning effects on air. The main factors to consider could include:

- Air pollution from burning pruning residues and the leaves and twigs washed from the olives before processing. The total volume of material burned is considerable but apparently no analysis has been made of the resulting air pollution.
- Air pollution resulting from chemical treatments, especially aerial spraying against olive fly (air-exposure to biocides).
- Carbon dioxide emissions resulting from tractors, especially in the case of repeated tillage.
- Carbon dioxide emissions resulting from the break-down of organic matter in the soil, which is accelerated by excessive tillage.

2.4 Biodiversity

The biodiversity value of olive plantations varies according to a range of interconnected factors, as presented below:

- The type of pesticides and herbicides used
- The quantity of pesticides and herbicides used
- The timing of pesticides and herbicides application
- The method, frequency and timing of weed-control and whether a seasonal under storage is allowed to become established beneath the trees.
- The presence of natural and semi-natural features, such as scrub, woodland, dry-stone walls, ponds, etc.

- The age of the trees.

The intensive application of techniques intended to increase production (especially frequent tillage and heavy herbicide and insecticide use) has a strongly detrimental effect on biodiversity and in general, results in a very significant reduction in the diversity and total numbers of flora and fauna.

Flora and invertebrate fauna are the foundations of biodiversity on which many of the typical communities of fauna in traditional olive plantations depend (mammals, birds, reptiles). Consequently, given the same soil, climate and variety of tree, low-yielding plantations tend to be of higher natural value than those from which high-yields are achieved through intensive management practices.

Biodiversity tends to be high in traditionally managed olive plantations as their structural diversity (trees and understorey) provides a variety of habitats. The older trees support a high diversity and density of insects which, together with the tree's fruit, provide an abundant supply of food. The low level of pesticide use allows a rich flora and insect fauna to flourish which, in turn, provides a valuable food source for a variety of avifauna.

Consequently, traditional olive plantations generally support a high diversity of wildlife, including reptiles, butterflies and other invertebrates, birds and small mammals. The trunks of older trees are also used by mammals and reptiles.

Concerning bird species, intensification of management is expected to be to the detriment of species that breed in the knarled trunks of old trees (e.g. little owls) or breed or feed in the vegetation around the bases of trees (quail and partridge) or between the trees on emi-open ground (woodlark and stone curlew) as many of these features are lost or modified through intensification.

The use of Mediterranean olive plantations as a food source by very large numbers of migrant passerine birds, both from northern and central Europe and from Africa, is well documented. Where pesticides are used intensively to control specific parasites, the overall insect population inevitably suffers and the trees' overall value as a food source for birds is reduced, although the olive fruit is still available to them.

It is noted that birds feeding on olives do not have a significant impact on production. The fruits taken are generally over-ripe, fallen to the ground and/or have been attacked by olive fly, and are therefore of little value. Birds may even help to control pests by eating infected fruits.

3 Good practices and guidelines

During last century, most economical processes have been split into sub-processes to achieve a better performance when working using massive production perspective. Agriculture has been linked to Agroindustry. Agriculture was the producer of outputs and Agroindustry was the consumer of outputs producing at the same time marketable goods to trade. No recycling or other similar processes have been taken into account until recently, and this has lead to a infra-use of possibilities of this dependencies: waste (sub-products) from agroindustry can be used as inputs (i.e, fertilizer or fuel) in agriculture and waste from agriculture can be used as well as inputs in the agroindustry (i.e, fuel and other materials). This looped logic can diminish environmental impact of both activities, when working applied and integral or holistic approach.

Success of industrial application of Good Practices has lead to the development of the so called Good Agricultural Practices, developed for agricultural processes. Application of Good Agricultural Practices is low and in most cases farmers apply them just for receiving money from Common Agricultural Policy. Thus, vast majority of farmers do not apply these practices or guidelines in order to protect the environment but for purely financial reasons. Few studies[1] have searched why most economical incentive is –nowadays- the only way to make farmers follow these recommendations. This lack of information is a severe handicap when trying to resolve huge environmental problems of present agriculture.

In case of guidelines for olive grove management, they are of doubtful use when they are too broad. Beaufoy (2000) stress that “it is important for the Good Agrarian Practice –GAP- to be developed at a local level, as conditions vary widely throughout the EU producer countries, even in a clearly Mediterranean sector such as olives”.

Until now, guidelines have been developed following results from “on site” environmental impact methodologies, not taking into account the whole production chain. There are not guidelines providing recommendations based on LCA studies. Only visible or semi-visible impacts of olive grove cultivation and olive oil production has been shown and took into account until now, omitting non visible impacts that only a full analysis through the whole chain can unmask.

When performing a LCA, most authors state that are clear differences between agricultural and industrial systems and it has been proved during last years that important specifications have to be made when applying this methodology in agricultural systems. A resume of main differences and thus, several problems of the methodology can be foreseen in the following table.

[1] In Spain, main work has been carried by Sánchez de Puerta (2005)

Table 1: Sistemas industriales vs. Sistemas agrarios (Milà i Canals, 2003)

Characteristics	***Industrial System***	***Agricultural Systems***
Site dependency	Very independent (except within the system boundaries with the nature: row materials and waste management)	Very dependent (possible to obtain certain degree of independence by using energy and infraestructures: greenhouses)
Systems boundaries	Clearly defined	Not very clear, physically and temporaly as well
Main impact sources	Materials and energy comsumption	Soil use, comsumption of materials and energy, emissions
Level of knowledge on the process	High (simple and pre-designed processes)	Rather poor (complex, natural processes)
Funcionality	One or more functions	Multifuncionality

These differences between systems can be transcribed when generating good practices (Table 2).

Table 2: Comparison of Good Practices in Industrial and Agricultural Systems

Characteristics	***Industrial System***	***Agricultural Systems***
Decisors	Few	Many
Variables in the process	Many	Uncountable
Complexity of processes	“Relatively easy”	Complex
Application: Site dependency	Low	High
Application: Unexpected parameters dependency (climate, pest, others)	Few	Many
Adoption of Good Practices	High	Low

The differences in the above presented characteristics in Industrial and Agricultural Systems, when generating Good Practices, indicate why practices or recommendations can only be developed in homogenous agricultural regions and by all actors involved in production and consumption of agricultural goods, in this case, in olive oil production.

Modern crisis of agriculture is a direct result of fail in its tree main assumptions (Sánchez de Puerta, 2005):

- Non renewable natural resources would maintain an stabilized price –ej, energy crisis in 1973
- Technological packages of Green Revolution can be generalized to global scale – ej, high environmental, social and economical costs in non industrialized countries
- Agricultural products and processes are innocuous for humankind and environment –no comments

As explained in Task 1.1, in EU (2004), many important changes in the CAP were made in the 1990s. Production limits helped to reduce surpluses and a new emphasis was placed on environmentally sound farming. Farmers had to look more to the market place, while receiving direct income aid, and to respond to the public's changing priorities. This shift of focus included a major new element – a rural development policy encouraging many rural initiatives while also helping farmers to diversify, to improve their product marketing and to otherwise restructure their businesses. A ceiling was put on the budget to reassure taxpayers that CAP costs would not run out of control. In 2003 a further fundamental reform was agreed. Farmers are no longer paid just to produce food. Today's CAP is demand driven. It takes consumers' and taxpayers' concerns fully into account, while giving EU farmers the freedom to produce what the market wants.

In the future, the vast majority of aid to farmers will be paid independently of what or how much they produce. In the past, the more farmers produced the more subsidy payments they received. Under the new system farmers will still receive direct income payments to maintain income stability, but the link to production has been severed. In addition, farmers will have to respect environmental, food safety and animal welfare standards. Farmers who fail to do this will face reductions in their direct payments (a condition known as 'cross-compliance'). Severing the link between subsidies and production (usually termed 'decoupling') will make EU farmers more competitive and market oriented. They will be free to produce according to what is most profitable for them while still enjoying a desirable stability of income (EU, 2004).

From an environmental point of view, promotion of environmental sound farming is made, among other sensitization and awareness activities, by economical support from the EU.

Actual CAP has two pillars, the first one, which is called the agricultural Pillar, in which farmers can receive, directs aids based in the product they are producing but performing "minimum" environmental measures know as cross-compliance. The second one, the Rural Development Pillar contains many aids for rural areas and agriculture, in which we can found Agri-Environmental measures. To receive aids, farmer must follow some previously settled conditions: the Good Agrarian Practices.

Organic Farming aids are among Agri-Environmental Measures, and have a more strict legislation (CEE 2092/91) to perceive money and must follow this normative as a basis for organic production and to sell products as organic. To ensure that the ecological practices are followed, one or more annual audits are carried by a Certification Company.

The EU (2004) is convinced that these schemes encourage farmers to provide environmental services which go beyond following good agricultural practice and basic legal standards. Aids may be paid to farmers who sign up voluntarily to agri-environment commitments for a minimum period of five years. Longer periods may be set for certain types of commitment, depending on their environmental effects. It is obligatory for Member States to offer such agri-environment schemes to farmers

4 Guidelines for improving the environmental performance of olive farming

4.1 General

Olive production constitutes a widespread agriculture activity in the southern Member States of the European Union with important environmental, social, cultural and economic considerations.

The requirement to integrate environmental concerns into Community policies, including agriculture policy, is the cornerstone of the European Union (EU) policy and legislation. However, until now there have been obstacles to achieving this integration, including a lack of clear and comprehensive information concerning the environmental affects of particular agricultural sectors and systems, and an absence of research into practical policy options. These absences are particularly apparent in the case of certain farming systems characteristic of the Mediterranean region, such as olive production, whose environmental effects have been studied less than farming systems more characteristic of central and northern Europe.

Towards this direction, an integrated management scheme must be developed and applied in the olive tree farming cycle that targets to the economical production of high quality olive fruits and olive, in parallel with the application of safe and ecological methods and practices (eco-production management), minimization of the use and negative effects of synthetic chemicals (agro-chemicals), protection of the natural resources e.g soil, surface/underground waters and atmosphere as well as protection of the farmers and the public health. Synoptically, the integrated olive tree farming aims at:

- The promotion of a scheme of olive production which is economically viable, respects the environment and also sustains the multi-dimensional functions and characteristics of agriculture
- The ensuring of a sustainable production of high quality olives and olive oil without the presence of pesticides and other agrochemicals residues
- The protection of the farmer’s health during handling agro-chemicals
- The protection and conservation of the biodiversity in the ecosystems of the olive tree plantations and also in the surrounding areas
- The use of natural regulating mechanisms in the ecosystems of the olive tree plantations
- The promotion of the long-term fertility of the soil by ecological means and practices
- The minimization of the pollution of water, soil and air by the use of synthetic chemicals (agro-chemicals).

For the improving of the existing environmental performance of the olive farming, several actions could be undertaken, which is divided into the following categories: improvement of current applied farming practices and providing effective information and training for farmers.

In each of the countries and areas studied, there is a potential for improving the environmental effects of olive production through changes in farming practices, particularly in the intensified-traditional systems and modern-intensive systems. In some cases, changes are required urgently in order to reduce severe and large-scale environmental impacts (for example, soil erosion) or to prevent impacts in the near future (for example, increasing over-exploitation of water sources and soil salinisation).

In certain areas, current practices are largely positive for the environment, with the exception of some farms where improvements could be achieved.

As an overall recommendation, it is desirable for each olive farmer to prepare a management plan, with expert advice, to address the specific environmental issues on the plantation. In the following, analytical information is given related to this topic.

In Andalucia, the most important spanish olive growing area, UNASUR an Union of Organizations of Olive Producers (Unión de Organizaciones de Productores de Aceituna), has written in 2004 a book of BPAs orientated to Olive Growing. In this book, the factors of production are shown as something that must be used in a rational way.

Table 3: Recommendation scope for a rational use of factors of production.

Rational use of…	**Recommendations regarding to…**
N fertilization	Foliar and soil analysis
	N availability
	Land characteristics
	Fertilizer choice
	Date and N application
	Waste package management
Pesticides	Pesticide choice
	Preparation of mixture treatment
	Pesticide application
	Pesticide transport and storage
	Waste package management
Soil	Soil management
	Soil covering
	Cover crop mowing

	Tillage
Water	Dry Land Olive Groves
	Irrigated Olive Groves
Harvesting	

Source: UNASUR, 2004.

4.2 General proposals

In reference to Environmental Good Practices, it is expected to achieve some specific objectives, through concrete, clear and easy recommendations and its application on industry. These specific objectives are shown hereafter:

Aspect	Objectives
ENERGY	Reduce energetic consumption Performance Optimization Combustion processes' improvement
WASTE	Minimize waste Appropiate waste management: storage, identification, remove...
ATMOSPHERE	Minimize chemical emissions Minimize noise emissions
LIQUID	Minimize spills Treatment improvement
SOIL	Avoid soil pollution

The application of the recommendations collected in a Environmental Good Practices Guide, should be the first step for an organization in order to achieve, in a easy way, an environmental improvement and its benefit.

The best way to manage properly an olive mill form an environmental point of view, is to implement an **ENVIRONMENTAL MANAGEMENT SYSTEM**. This is the best "Good Practice" that can be recommended, because an **Environmental Management System** on an olive mill guarantees, among others:

Legislative fulfilment on environmental matters
Objectives, Indicators and Environmental Programs establishment, focused to minimize: - Water or Soil spills - Atmospheric emissions - Waste generation - Energy consumption - Material consumption - Water consumption

Proper management and treatment of the generated waste through authorized managers
Worker training and motivation on environmental matters
Environmental Emergency Plan existence
Proper maintenance of facilities, minimizing leaks

There are several Environmental Management standards, but the most popular is the ISO 14.001 standard. This standard belongs to the ISO 14.000 standards family, which includes the LCA 14.040 standard used in this study.

At a European level we can base our Environmental Management System on (CE) 761/2001 regulation, Eco-Management and Audit Scheme (EMAS)

All of them have a voluntary basis and, as a complementary fulfilment guarantee, they have a certificate and they are subjected to periodical external audits by an independent third part.

4.3 Selection of the plantation site

Olive trees can grow in nutrient-poor but well-drained soils. They need full sun for the production of fruit and slight cold for the fruits to set. Olive trees should not be planted in areas where temperature falls below -5oC because they do not tolerate very low temperatures (they get damaged by frost). A reliable criterion for selecting an area for plantation of olive trees is the presence of undamaged olive trees for at least twenty years in the surrounding area. Olive trees are also damaged from hot and dry air, particularly during flowering and fruit setting. Also, in areas with low air circulation and high humidity, diseases such as leaf spot could be appeared.

Another criterion for the selection of the plantation site is the annual rainfall in the area. In particular, in areas with low rainfall (200-300 mm), olive yield is satisfactory in soils with good water retaining capacity, unless irrigation is applied. In high rainfall areas (400-600 mm) olive yield is good on condition that adequate drainage is provided. In fields with high slopes, contour cultivation on terraces must be employed. In this case, specialized tractors (caterpillar or crawler tractors) and other vehicles should be used to minimize the danger of overturn.

Additionally, new plantations must be avoided at areas with slopes higher than 25%, unless terrace cultivations are applied.

Table 4: Summary of guidelines for the selection of the plantation area

Proposed actions	**Potential benefit**
Olive trees should not be planted in areas where temperature falls below -5^{o}C	Avoidance of olive trees damage by frosts
Avoidance of areas with hot and dry air	Avoidance of olive trees damage during flowering and fruit setting.
Avoidance of areas with low air circulation and high humidity, diseases such as leaf spot could be appeared.	Diseases such as leaf spot are avoided
▪ In low rainfall areas (200-300 mm), the soils must have good water retaining capacity or must be irrigated ▪ In high rainfall areas (400-600 mm), the drainage must be adequate ▪ In areas with high slopes, contour cultivation on terraces must be applied. Also, tractors (caterpillar or crawler tractors) and other vehicles should be used to minimize the danger of overturn.	▪ Existence of effectual quantity of water for the roots of the olive trees ▪ Well –balanced growth of olive trees ▪ Satisfactory yield of olive fruits

4.4 Planting set-out

Olive tree planting scheme is selected according to the cultivation system that will be applied (intensive/non-intensive). For intensive cultivation, in areas with fertile soil and sufficient rainfall (or irrigation), trees are planted densely e.g. a density of 200-300 trees/ha, depending on the olive tree variety. In areas with less fertile soils and low rainfall, planting density is reduced accordingly. Moreover, cultivations with more of 300 trees/ha should be avoided since they require management practices that are unfavorable e.g. application of herbicides at the entire surface of the soil.

Table 5: Summary of guidelines for the planting layout

Proposed actions	**Potential benefit**
For intensive cultivation, in areas with fertile soil and sufficient rainfall or irrigation, trees are planted densely e.g. a density of 200-300 trees/ha, depending on the olive tree variety.	▪ Well –balanced growth of olive trees ▪ Satisfactory yield of olive fruits
In areas with low fertile soil and low rainfall, planting density is reduced accordingly.	▪ Well –balanced growth of olive trees ▪ Satisfactory yield of olive fruits
Cultivations with more of 300 trees/ha should be avoided	▪ Well –balanced growth of olive trees ▪ Satisfactory yield of olive fruits ▪ Avoidance of unfavorable management practices such as application of herbicides at the entire surface of the soil

4.5 Preparing the site for plantation

Before planting of the new trees, some necessary cultivation activities must be carried out, such as uprooting of other trees and bushes, leveling the soil, construction of terraces where it is required, etc. If the field is uprooted, it is suggested to cultivate grains or legumes for a period of 1-2 years, in order to remove all remaining roots from previous crops and minimize the incidence of root decay in the new trees. Deep ploughing may also be necessary to destroy weeds in combination with/without herbicides. Then, the field is ploughed to facilitate the growth of the root system of the new trees. Moreover, phosphate and potash fertilizers are added with the last ploughing, which are used by the trees during the first years of growth. Additionally, when the content of the soil in organic matter is lower than 1% (cultivations without irrigation) or 2% (cultivations with irrigation) must be improved, by adding natural organic fertilizers such as manure or compost.

Before adding any fertilizer, it is strongly recommended to perform soil analysis by taking samples from different spots and depths in the field (30, 60, 90 cm). The analyses of the soil should be include the following: pH, CaCO3, organic matter, macro elements (Phosphorus, Potassium, Magnesium) and trace elements (e.g. Boron).

Table 6: Summary of guidelines for preparing the site for plantation

Proposed actions	**Potential benefit**
Before planting, some necessary actions must be carried out, such as uprooting of other trees and bushes, leveling of the soil, construction of terraces where it is required, etc.	▪ Facilitation of the boscage of the new trees ▪ Well-balanced growth of the trees
If the field is uprooted, it is advised to cultivate grains or legumes for a period of 1-2 years, in order to remove all remaining roots from previous crops	▪ Facilitation of the boscage of the new trees ▪ Well-balanced growth of the trees ▪ Minimization of the incidence of root decay in the new trees
Deep ploughing in combination with herbicides (when is necessary).	▪ Facilitation of the growth of the root system of the new trees ▪ Well-balanced growth of the trees ▪ Destroy of weeds
Addition of inorganic fertilizers e.g. phosphate and potash fertilizers with the last ploughing.	▪ Facilitation of the growth of the root system of the new trees ▪ Well-balanced growth of the trees ▪ Use of inorganic nutrients by the trees during the first years of growth
Addition of natural organic fertilizer in soils with content of organic matter lower than 1% (cultivations without irrigation) or 2% (cultivations with irrigation)	▪ Improvement of the characteristics of the soils (drainage, aeration, etc.) ▪ Facilitation of the growth of the root system of the new trees ▪ Well-balanced growth of the trees ▪ Well-balanced uptaking of nutrients by the roots of the trees

4.6 Planting of new trees

The time of planting of new trees varies from area to area, according to the climate conditions. In particular, in areas with mild climate, planting takes place in winter (November-December), while in areas with lower temperatures, it is suggested to plant the trees in February-March.

Planting is made into holes that have been dug manually or mechanically, in dimensions of about 60 x 40 cm (manual digging) or 20 x 30 cm (mechanical digging). Planting depth should be the same as in the nursery. In dry areas, planting holes must be 5-10 cm deeper.

Digging holes can raise certain problems, since in sandy soils, the walls of the hole may fall in, while in clay soils the walls are compacted. As a result, the root system needs more time to grow beyond these walls. The trees are planted together with the root ball and the hole is then filled with soil. Special attention must be given not to damage the roots when pressing the earth down to firm the plants. After planting, the surrounding earth could be covered with straw to minimize water loss from the soil.

Young trees should be irrigated regularly during the first 2-3 years and fertilized with nitrogen every year. In addition, it is necessary to control weeds in time and take plant protection measures against pests and other diseases.

As already mentioned, soil analysis must be preceded before planting in order to determine the necessary amounts of phosphate and potassium fertilizers. Additionally, soil analysis will indicate if calcium is necessary. Otherwise, in case where no phosphate and potassium have been applied in the last years, the following amounts of fertilizers are recommended: 1000-1500 kg/ha 0-20-0 and 500-800 kg/ha 0-0-50.

These amounts are adequate to cover the needs in phosphate and potassium for a time period of 5-8 years. In the next year, after the beginning of the new vegetation, 3-4 applications of ammonium nitrate (20-30 g/tree/application) are necessary followed by irrigation. The same is applied in subsequent years until the trees enter the productive stage, increasing gradually the quantity of fertilizer. Additionally, when necessary, natural organic matter (e.g. manure) should be added in the soil in order to improve its fertility.

Table 7: Summary of guidelines for planting of new trees

Proposed actions	**Potential benefit**
In areas with mild climate, planting takes place in November-December.	▪ Facilitation of the growth of the root system of the new trees
Planting is made into holes that can be dug manually (in dimensions of about 60 x 40 cm) or mechanically (in dimensions of 20 x 30 cm). Planting depth should be the same as in the nursery. In dry areas, planting holes must be 5-10 cm deeper.	▪ Facilitation of the growth of the root system of the new trees
The walls of the holes must be efficient In light (sandy) soils, the walls of the hole fall	▪ Avoidance of falling in of the walls in light (sandy) soils

in, while in heavy (clay) soils the walls are compacted.	▪ Avoidance of compacting of walls ▪ In this case, the root system takes more time to grow beyond these walls.

4.7 Pruning

Pruning is necessary to adjust the trees to the climatic conditions of the specific area and increase the productivity of the plantation.

There are three main types of pruning, as described below:

- Regulated pruning: It aims to develop the tree's frame and is of great importance in the first years of the tree's life.
- Pruning for fruiting: It aims to induce productive branches to form fruits leaving the structural branches unaffected. Moreover, it maintains uniform production in terms of yield and quality (a feature that is important in table olive varieties).
- Renovating pruning: It aims to stimulate sprouting in order to rejuvenate senescent trees.

More analytically:

Regulated pruning aims at developing a tree shape in the first years of growth to facilitate cultivation, spraying and especially harvesting. At this stage, very severe pruning should be avoided, because it delays trees from entering the fruiting period. The most common shaping system is the "free spherical shape". To form this shape, one-year-old trees are cut back to 60-80 cm above the ground. In the first year, the main focus is to create side branches around the central axis to a height of 30-60 cm from the ground. In the following years, pruning is very mild aiming at the removal of broken shoots or shoots that intersect to each other. After the tree has developed well, 3-5 main branches are chosen around the central axis, with 20-30 cm distance among each other. When the tree enters the fruiting period, and if no severe pruning is performed, it gradually takes a free spherical shape.

For intensive cultivation, short pruning shapes are desired, namely the "short cup" and the "bush". In these pruning shapes, branching takes place very close to the ground, at a height of 30-40 cm, while in the latter no pruning is done in the first 5-6 years. Afterwards, only weak shoots and top branches exceeding 3 m are removed. The bush shape has certain advantages for intensive cultivation systems, such as: i. earlier fruiting period ii. higher yields per hectare compared with other pruning shapes (increased productivity) iii. lower labour demands and costs, due to the application of harvesting from the ground (without using ladders).

However, both shapes present a major disadvantage because they obstruct mechanical cultivation of the soil. In addition, harvest is difficult particularly for fruits fallen on the ground. An improved short shape without the disadvantages of short cup and bush shape is the monoconical pruning. Within this pruning practice, the tree has one central trunk and is pruned into a cone tree type shape.

Pruning for fruiting: Olive trees produce fruits in previous year branches. Very vigorous branches are not productive (they have only vegetative buds) and weak branches produce few fruits. For this reason, the aim of pruning is to induce branches to form fruits, ensure good lighting conditions and maintain the fruiting zone active and vigorous.

The above goals are difficult to be achieved in densely planted trees, due to the reduced lighting of the crown. In this case, the fruiting zone is restricted on the top branches and in certain areas of the south part of the canopy, where there is more light. The productivity of these trees is greatly reduced when their tops are pruned to give a shorter shape because a significant part of their canopy is removed.

In the productive stage, it is suggested to perform a mild pruning every year to remove dead and dense branches from the fruiting zone. This is necessary because the fruiting zone has the tendency to produce short and dense shoots with time. The aim of this mild pruning is to improve the length of the shoots and ensure good lighting throughout the fruiting zone. It must be noted that this pruning must be severe for trees growing in arid and infertile soils to reduce the surface area of the canopy, saving thus nutrients and water for the new fruiting growth. On the contrary, trees growing in fertile soils with good fertilization and irrigation, must be subjected to less severe pruning because there is adequacy of nutrients and water for both the present vegetation and the development of new fruiting growth. In this case, severe pruning results in the development of sucker shoots.

In the case of table olive varieties, pruning must also improve the size of the fruits. For this reason, it is suggested to thin off excessive fruits right after fruit-setting, especially in high yield years. In addition, proper pruning can also improve alternate bearing. In this case, a severe pruning is suggested in the winter preceding the year of high yield, by cutting off low vigour shoots.

Renovating Pruning: The olive trees has the ability to produce new shoots from almost any part of its wood, making thus possible to renovate senescent or trees damaged by frost. Old or low yield trees can be rejuvenated by cutting off their trunk at a low height or at the point of ramification. For partial renewal or reduction of canopy surface in densely planted trees, pruning is performed at the branches or their first ramifications at a desirable height. New vivid shoots will develop from the cutting points, the most appropriate of which are chosen for the new shape of the tree. The new tree enters again the fruiting period after 3-5 years. When damage by frost occurs, trees are left unattended for one year to estimate the real extension of the damage. From the new developed shoots, the new branches will be formed and all the damaged parts will de cut off.

Pruning Period

Pruning of olive trees can be done right after harvest. For table olive varieties, pruning begins in November-December for green olives or February-March for black olives. In general, pruning can be performed from autumn to the first months of spring, but it should be delayed in areas with high risk of frost. In all cases, the following parameters must be taken into consideration: The level of rainfall in autumn and winter, the yield of the previous year, the vegetative condition (vigour) of the tree when pruning, the type of end product (table olives or olives for the production of olive oil), the planting density and the pruning system applied.

Finally, pruning residues should be incorporated in the soil, rather than burnt, in order to increase the organic content and the fertility of the soil (with the exception of infection of the tree by Verticillium dahlia) ii. avoid the emissions to the air during combusting of the residues.

Table 8: Summary of guidelines for pruning of trees

Proposed actions	Potential benefit
<u>Regulated pruning</u> It is applied in order to develop a tree shape in the first years of growth. The most common shaping system is the "free spherical shape": One-year-old trees are cut back to 60-80 cm above the ground in order to create side branches around the central axis to a height of 30-60 cm from the ground. In the following years, pruning is very mild aiming at the removal of broken shoots or shoots that intersect to each other. After the tree has developed well, 3-5 main branches are chosen around the central axis, with 20-30 cm distance among each other. When the tree enters the fruiting period, it gradually takes a free spherical shape.	▪ Facilitation of the cultivation ▪ Facilitation of spraying ▪ Facilitation of harvesting.
For intensive cultivation, short pruning shapes are desired ("short cup" and "bush"). In these pruning shapes, branching takes place very close to the ground, at a height of 30-40 cm, while in the latter no pruning is done in the first 5-6 years. Afterwards, only weak shoots and top branches exceeding 3 m are removed.	▪ Leading to earlier fruiting period ▪ Higher yields per hectare are obtained, compared with other pruning shapes (increased productivity) ▪ Lower labour demands and costs, due to the application of harvesting from the ground (without using ladders). ▪ The mechanical cultivation of the soil is not

Application of a monoconical pruning shape. The tree has one central trunk and is pruned into a cone tree type shape.	obstructed
<u>Renovating Pruning</u> It is applied by cutting off the trunk of the trees at a low height or at the point of ramification. For partial renewal or reduction of canopy surface in densely planted trees, pruning is performed at the branches or their first ramifications at a desirable height. New vivid shoots will develop from the cutting points, the most appropriate of which are chosen for the new shape of the tree. When damage by frost occurs, trees are left unattended for one year to estimate the real extension of the damage. From the new developed shoots, the new branches will be formed and all the damaged parts will de cut off.	▪ Old or low yield trees can be rejuvenated ▪ The new tree enters again the fruiting period after 3-5 years ▪ Rejuvenation of trees that have got damage by frosts.
<u>Pruning Period</u> Pruning of olive trees can be done right after harvest. For table olive varieties, pruning begins in November-December for green olives or February-March for black olives. In general, pruning can be performed from autumn to the first months of spring, but it should be delayed in areas with high risk of frosts.	▪ Balancing of vegetation with fruit yield ▪ Minimization of the non productive period ▪ Prolongation of the productivity of the trees ▪ Delay of senescence ▪ Saving of soil water (in non-irrigated orchards) ▪ Allowing sufficient insinuation of the solar light ▪ Facilitation of spraying ▪ Improvement of the aeration of the leaves, fact

	that results in protection by diseases (e.g. *Spilocaea oleaginum*) ▪ Facilitation of harvesting
<u>Management of pruning residues</u> Pruning residues should be incorporated in the soil, rather than burnt (with the exception of infection of the tree by *Verticillium dahlia*). In the cases when the residues of pruning are burnt, the remaining ash should be spread in the soil of the cultivations	Incorporation of pruning residues in the soil: ▪ Increasing of the organic content of the soil (natural fertilization) ▪ Avoidance of emissions to the air caused by burning of the residues Spreading of ash from burning of pruning residues: ▪ Trace elements are available for the growth of the trees

4.8 Irrigation

Olive trees have small leaves with a protective coating and hairy undersides that reduces the transpiration, in order to be enabled to grow in hot and dry climate. Feature facilitates the cultivation of olive trees in areas where other trees can not carry through. However, this defense system is at the expense of growth and productivity of the tree. Thus, olive yield is greatly increased by applying small amounts of water. However, if maximum yields are desired, higher amount of water will be needed, on condition that soil humidity does not become excessive. In general, irrigation is necessary when:

- the rainfall in the area is inadequate.
- there is high time period of drought (enough rainfall distributed only during the winter, leaving the soil without humidity in the critical periods of spring and autumn).
- the soil is sandy or gravelly with low water retaining capacity.

Irrigation is recommended especially in table olive varieties where large fruit size is favorable. It is also necessary in intensive plantations with densely planted trees in order to obtain maximum production. Irrigation also enhances the effectiveness of fertilization and pruning. Finally, it may minimize the phenomenon of alternate bearing.

The critical periods for water stress of olive trees as well as the respective effects are presented in Table 6.

Table 9: Critical periods for water stress of olive trees and respective effects

Growth stage	Effect
- Flower bud development - Bloom - Fruit set - Shoot growth	▪ Reduced flower formation ▪ Incomplete flowering ▪ Poor fruit-set ▪ Increased alternate bearing ▪ Decreased shoot growth
1st stage of fruit growth due to cell division shoot growth	▪ Small fruit size due to decreased cell division ▪ Fruit shrivel ▪ Decreased shoot growth
3rd stage of fruit growth due to cell enlargement of shoot growth	▪ Small fruit size due to reduced cell expansion ▪ Fruit shrivel ▪ Decreased shoot growth

Shriveled fruits may obtain again their turgidity after irrigation. For this reason, it is recommended to irrigate table olive varieties, especially during the last period of fruit development, to improve their size and quality. However, over irrigation may have negative effects in the case of black olives resulting in delayed maturity. Late irrigation may also lead to new vegetative growth that is susceptible to winter frosts. Many olive orchards around the Mediterranean are not irrigated. In those where irrigation is applied, a variety of methods is employed including, flood, furrow, sprinklers, hanging drippers, surface drip irrigation, and during the last years also sub-surface drip irrigation.

In surface drip irrigated plantations, various practices are applied. In most cases, one dripline per row of trees is placed on the ground. Usage of two driplines per row is also applied. In some orchards, the dripline is hung on the trees to enable criss-cross cultivation.

Irrigation frequency depends on water availability so as to ensure sufficient soil moisture at the critical stages of the crop, as described in Table 6. The amount of water depends on many factors such as soil type, age of trees, size of the trees etc.

It must be noted that the irrigation of olive plantations often has little agronomic foundation, in terms of the quantities and timing of water applications and many farmers use more water than is necessary for the plantation and the soil. For traditional low tree densities, the application of a constant amount of water, 80-120 l/day/tree (in heavy/clay soils) is adequate. Additionally, the amount of water during seasonal irrigation should not exceed the 250 mm.

Olive trees are very sensitive to over irrigation and will not perform well in waterlogged soils. Waterlogged soil, often a result of poor drainage, causes poor soil aeration and root deterioration and can lead to the death of the trees. Trees cultivated in saturated soils are more susceptible to varying weather conditions and soil borne pathogens such as Phytophthora and Verticillium.

Table 10: Summary of guidelines for irrigation

Proposed actions	**Potential benefit**
Irrigation is required when: i. the rainfall in the area is inadequate ii. there is enough rainfall distributed only during the winter, leaving the soil without humidity in the critical periods of spring and autumn iii. the soil is sandy or gravelly with low water retaining capacity. Irrigation methods: flood, furrow, sprinklers, hanging drippers, surface drip irrigation, and sub-surface drip irrigation. Surface irrigation methods: one dripline (mainly) or two driplines per row of trees. In some orchards, the dripline is hung on the trees to enable criss-cross cultivation. For traditional low tree densities, the application of a constant amount of water, 80-120 l/day/tree (in heavy soils) is adequate. Additionally, the amount of water during seasonal irrigation should not exceed 250 mm. Olive trees are very sensitive to over irrigation and will not perform well in waterlogged soils. Waterlogged soil, often a result of poor drainage, causes poor soil aeration and root deterioration and can lead to the death of the trees. Trees cultivated in saturated soils are more susceptible to varying weather conditions and soil borne pathogens such as *Phytophthora* and *Verticillium*.	▪Facilitate the cultivation in intensive plantations with densely planted trees for maximum production. ▪Enhancement of the effectiveness of fertilization ▪Enhancement of the effectiveness of pruning. ▪Minimization of the phenomenon of alternate bearing. ▪Achievement of sufficient soil moisture at the critical stages of the crop. ▪Application of the quantity of water that is desirable for the health of the plantation and the state of the soil ▪Irrigation of olive plantations in a good timing

4.9 Fertilization

In many cases farmers apply much more fertiliser than the crop really needs. Most integrated production systems propose fertilization on basis of soil and leaf analysis of tree requirements. In particular:

4.9.1 Nitrogen

Nitrogen fertilizers

The most common nitrogen fertilizers for olive tree growing are the following:

Ammonium sulfate. It is available in two forms: Crystallized (21-0-0) and Granular (20.5-0-0). Ammonium sulfate contains also 23-24% sulphur, which is normally an additional benefit. This fertilizer makes the soil slightly more acidic and can be used in soils with alkaline pH level. The granular form is ideal for mechanical application e.g. with centrifugal fertilizer distributor. To minimize losses, due to ammonium evaporation, it is recommended to incorporate the fertilizer into the soil. Ammonium sulfate is available within a few weeks, after nitrification by microorganisms into nitrate. It is preferred when fertilization takes place early in the cultivating period.

Ammonium nitrate. It is available in granular form and contains 33-34% nitrogen. It is very soluble into the soil, where with little humidity offers nitrogen to trees in both nitrate and ammonium forms. Plants readily absorb nitrates; however, excessive amounts are not absorbed by the roots, leaching thus to the underground table water and polluting the environment. Ammonium nitrate becomes available to the trees in a few weeks. It has less residual activity than ammonium sulfate. This fertilizer may acidify the soil, so it should not be applied in acid soils, even in neutral ones.

Ammonium calcium nitrate. It is a compound granulated fertilizer containing 26-28% nitrogen as ammonium nitrate and also calcium carbonate. It can substitute ammonium sulfate and ammonium nitrate in acid soils as well as in humid areas to minimize risk of soil acidification.

Urea. It is water-soluble containing 45-46% nitrogen by weight. It provides nitrogen in ammonium form, which is then nitrified. Nitrogen in the form of ammonia is slightly volatile, and because urea is converted to ammonia before being nitrified, it is worth burying this fertilizer slightly below the surface of the soil to minimize losses. Urea causes soil acidification, whereas in calcareous and alkaline soils a part is lost due to evaporation of ammonia. Due to its high solubility in water, urea can be applied as foliar feeding. To avoid toxicity effects to the trees, the amount of di-urea impurities should not exceed 2% for soil application and 0.25% for foliar sprays.

Nitrogen application

Nitrogen is the most essential element influencing both vegetative and fruit production. It can also affect, in an indirect manner, the extent of alternate bearing. The response of olive trees to nitrogen is more obvious in low fertility soils, when soil moisture is not a restrictive factor. Depending on the current soil fertility and humidity, it is recommended to apply 500-1500 g nitrogen per tree (for low trees densities) or 50-150 kg nitrogen per hectare (for high trees densities –more than 100 trees/ha). It must be noted that 1kg N = 5 kg approximately of ammonium sulfate, 3 kg ammonium nitrate, 4 kg calcium nitrate or 2 kg urea.

In dry farming conditions, the amount of nitrogen fertilizer depends on the annual rainfall and the available soil moisture. More specifically:

i. in areas with mean annual rainfall less than 400 mm, the addition of nitrogen should be made with extra care. In these areas it is suggested to add 100 g/tree/100 mm of rainfall (or 10 kg/ha/100 mm of rainfall).

ii. in areas with mean annual rainfall ranging between 400-700 mm, the amount of nitrogen could be increased proportionally to 1500 g/tree.

iii. in areas with mean annual rainfall higher than 700 mm, or in irrigated olive orchards, the dosage of nitrogen depends on the soil fertility, up to 1500 g/tree.

The olive tree farmers can assess the effectiveness of nitrogen fertilization and amend it, if it is necessary, by examining the length of the new vegetation (if the length of the new vegetation is not sufficient, the amount of nitrogen must be increased, provided that no other critical factors exist e.g. diseases, root damage, etc) as well as by carrying out leaf analysis (nitrogen fertilization is adjusted so that the amount of nitrogen in leafs ranges between 1.6-1.8% w/w, during winter).

A critical period, in which trees should have available nitrogen, is floral induction, from the beginning of March to June. In dry farming orchards, nitrogen fertilizer is added to the soil in December – February in order to have available nitrogen during the critical period. In areas where low rainfall prevails, nitrogen should be applied in the beginning of floral induction period, while in areas with higher rainfall, it is common practice to apply nitrogen in the end of this period. Also, it must be noted that excessive amounts of nitrogen before fruit setting may lead to high fruit load resulting in small size fruits and alternate bearing. On the contrary, sufficient nitrogen amounts after fruit setting contribute to vegetation and high yield in the next year. Nitrogen application in the critical stages can be done with foliar fertilization. Urea gives good results at a dilution up to 3-4%. Foliar fertilization is effective in dry farming orchards where the absorption of nitrogen through the root system is very restricted.

Table 11: Summary of guidelines for nitrogen application

Proposed actions	**Potential benefit**
Depending on the existing soil fertility and humidity, it is recommended to apply 500-1500 g nitrogen per tree (for low trees densities) or 50-150 kg nitrogen per hectare (for high trees densities –more than 100 trees/ha). It must be noted that 1kg N = 5 kg approximately of ammonium sulfate, 3 kg ammonium nitrate, 4 kg calcium nitrate or 2 kg urea. In areas with mean annual rainfall less than 400 mm, it is suggested to add 100 g/tree/100 mm of rainfall (or 10 kg/ha/100 mm of rainfall). In areas with mean annual rainfall ranging between 400-700 mm, the amount of nitrogen could be increased proportionally to 1500 g/tree. In areas with mean annual rainfall higher than 700 mm, or in irrigated olive orchards, the dosage of nitrogen depends on the soil fertility, reaching 1500 g/tree. The olive tree farmers can assess the effectiveness of nitrogen fertilization and amend it, if it is necessary, by examining the length of the new vegetation (if the length of the new vegetation is not sufficient, the amount of nitrogen must be increased, provided that no other critical factors exist e.g. diseases, root damage, etc) as well as by carrying out leaf analysis (nitrogen fertilization is adjusted so that the amount of nitrogen in leafs ranges between 1.6-1.8% w/w, during winter). A critical period, in which trees should have available nitrogen, is floral induction, from the beginning of March to June. In dry farming orchards, nitrogen fertilizer is added to the soil in December – February in order to have available nitrogen during the critical period. In areas where low rainfall prevails, nitrogen should be applied in the beginning of floral induction period, while in areas with higher rainfall, it is common practice to apply nitrogen in the end of this period.	These fertilizers make the soil slightly more acidic and can be used in soils with alkaline pH level for pH adjustment . Rational use of fertilizers results in well-balanced growth of the trees and the fruits The soil has appropriate amount of nutrients that are available for the root system of the trees The roots of the trees uptake the amount of nutrients in a well-balance and gradual way. By applying a rational use of fertilizers (avoidance of using of fertilizers in excess) fertilizers residues do not remain in the soil. As a result: i. Surface run-off of rainfall water polluted with nitrogen compounds is avoided ii. leaching of polluted water to the underground water is eliminated iii. pollution of surface water is avoided iv. the phenomenon of the eutrophication is eliminated

Excessive amount of nitrogen before fruit setting may lead to high fruit load resulting in small size fruits and alternate bearing. On the contrary, sufficient nitrogen amounts after fruit setting contribute to vegetation and high yield in the next year. Nitrogen application in the critical stages can be done with foliar fertilization (e.g. urea at a dilution up to 3-4%). Foliar fertilization is effective in dry farming orchards where the absorption of nitrogen through the root system is very restricted.	

4.9.2 Phosphorus

Phosphorus fertilizers

For soil application it is suggested to use: i. the simple superphosphate (0-20-0) and the triple superphosphate (0-46-0). For application through the irrigation system, crystal soluble fertilizers are suggested such as: mono-ammonium phosphate (12-61-0) and bi-ammonium phosphate (21-53-0).

Phosphorus application

The presence of this nutrient is common in the soil and phosphate fertilization is not really necessary, especially when 11-15-15 compound fertilizers have been used for several years in the field. Phosphorus is not really necessary in the following cases: i. in olive orchards where high quantities of phosphate fertilizers have been used repeatedly in the previous years ii. in olive orchards, in which only small amounts of phosphate must added due to low soil humidity.

On the contrary, phosphate fertilization can be necessary: i. in acidic soils ii. soils containing high amounts of calcium carbonate iii. for orchards planted in shallow, infertile soils iv. in new irrigated olive orchards (1-10 years old) in which ample nitrogen is used every year.

Phosphate deficiency is easily determined by leaf analysis. Phosphate addition is necessary when the concentration of the nutrient in the leaves ranges from 0.09-0.10 % in the winter and the ratio N/P is around 20. Higher concentrations in the leaves or higher N/P ratios indicate that phosphate fertilization must be applied.

When phosphate fertilization is necessary, it should not exceed 1/3-1/5 of the amount of nitrogen added. In particular, if 1 kg N/tree (i.e. 5 kg ammonium sulfate) is added, the corresponding amount of phosphate should not exceed 200-350 g P_2O_5/tree (i.e. 1.0-1.7 kg 0-20-0). It is suggested to add 500 g P_2O_5/tree (i.e. 2.5 kg 0-20-0) in a two-year period. In the case of severe phosphate deficiency, an amount of 4-5 kg P_2O_5/tree (i.e. 20-25 kg 0-20-0) is added in trees at the stage of full production. For younger trees, lower quantities (1-8 kg 0-20-0) are added, depending on the age and the development stage of the trees.

The characteristic symptom of phosphate deficiency is widespread chlorosis of the leaves. However, it is not a safe diagnostic criterion because it is often confused with other causes (e.g. nitrogen deficiency). Safe diagnosis can be done by leaf analysis.

Table 12: Summary of guidelines for Phosphorus application

Proposed actions	**Potential benefit**
The presence of this nutrient is common in the soil and phosphate fertilization is not really necessary in the following cases: i. in olive orchards where high quantities of phosphate fertilizers have been used in the previous years ii. in olive orchards, in which only small amounts of phosphate must added due to low soil humidity. On the contrary, phosphate fertilization can be necessary: i. in acidic soils ii. soils containing high amounts of calcium carbonate iii. for orchards planted in shallow, infertile soils iv. in new irrigated olive orchards (1-10 years old) in which ample nitrogen is used every year. Phosphate deficiency must be determined by leaf analysis. Phosphate addition is necessary when the concentration of the nutrient in the leaves ranges from 0.09-0.10 % in the winter and the ratio N/P is around 20. Higher concentrations in the leaves or higher N/P ratios indicate that phosphate fertilization must be applied. When phosphate fertilization is necessary, it should not exceed 1/3-1/5 of the amount of nitrogen added. In particular, if 1 kg N/tree (i.e. 5 kg ammonium sulfate) is added, the corresponding amount of phosphate should not exceed 200-350 g P_2O_5/tree (i.e. 1.0-1.7 kg 0-20-0). It is suggested to add 500 g P_2O_5/tree (i.e. 2.5 kg 0-20-0) in a two-year period. In the case of severe phosphate deficiency, an amount of 4-5 kg P_2O_5/tree (i.e. 20-25 kg 0-20-0) is added in trees at the stage of full production. For younger trees, lower quantities (1-8 kg 0-20-0) are added, depending on the age and the development stage of the trees.	These fertilizers make the soil slightly more acidic and can be used in soils with alkaline pH level for pH adjustment . Rational use of fertilizers results in well-balanced growth of the trees and the fruits The soil has appropriate amount of nutrients that are available for the root system of the trees The roots of the trees uptake the amount of nutrients in a well-balance and gradual way. By applying a rational use of fertilizers (avoidance of using of fertilizers in excess) fertilizers residues do not remain in the soil. As a result: i. Surface run-off of rainfall water polluted with phosphorus compounds is avoided ii. leaching of polluted water to the underground water is eliminated iii. pollution of surface water is avoided iv. the phenomenon of the eutrophication is eliminated

4.9.3 Potassium

Potassium fertilizers

The following types of potassium fertilizers are usually applied in olive trees:

Potassium sulfate. It is available in powder and granulated form for soil application, as well as in water-soluble form for foliar feeding and application with irrigation. It contains the equivalent of 48-50% K_2O and 17% sulfur. It has low salinity index and it is preferable in alkaline soils. The solubility of water soluble potassium fertilizers decreases with temperatures below 20°C, a fact that must be taken into account when potassium fertilizers are applied with irrigation.

Potassium nitrate. It is available in water-soluble (crystallized) and granulated form. It contains 46% K_2O and 13% nitrogen in the form of nitrates. It is recommended for foliar sprays and application through the irrigation system.

Patentkali®. It is a mixed fertilizer of potassium sulfate and magnesium sulfate. It contains the equivalent of 28% K_2O, 8% Mg and 18% S. It is a registered trademark of BASF, recommended for crops that require a lot of magnesium and which are sensitive to chloride.

Potassium application

This element is of great importance for the cultivation since olive trees are demanding in this nutrient. High amounts of potassium are removed from the soil with fruit harvest and pruning, particularly in high yield seasons. Regular potassium fertilization is required in order to maximize yield and quality, especially in orchards where no potassium fertilizer has been added for several years.

The amount of potassium should be determined in combination with nitrogen. In olive orchards, in which no potassium has been used in the past, it is preferable to add twice as much potassium as nitrogen. In particular, if 0.5 kg N/tree (i.e. 2.5 kg ammonium sulfate) is applied, then 1 kg potassium/tree (i.e. 2 kg potassium sulfate) must be added. In time, potassium dosage is adjusted to be equal to nitrogen. After high yield seasons, it is preferable to increase potassium to supplement the amount that is being removed. Leaf analysis, wherever it is possible, may give better direction for potassium fertilization.

Table 13: Summary of guidelines for potassium application

Proposed actions	**Potential benefit**
Olive trees are demanding in this nutrient. High amounts of potassium are removed from the soil with fruit harvest and pruning, particularly in high yield seasons.	Maximization of yield and quality of the fruits

The amount of potassium should be determined in combination with nitrogen. In olive orchards, in which no potassium has been used in the past, it is preferable to add twice as much potassium as nitrogen. In particular, if 0.5 kg N/tree (i.e. 2.5 kg ammonium sulfate) is applied, then 1 kg potassium/tree (i.e. 2 kg potassium sulfate) must be added. In time, potassium dosage is adjusted to be equal to nitrogen. After high yield seasons, it is preferable to increase potassium to supplement the amount that is being removed.	

4.9.4 Boron fertilizers

For boron deficiency treatment, sodium pyroborate can be added in the soil. For foliar application or through irrigation, water-soluble boron can also be used.

4.9.5 Deficiencies of nutrient elements

4.9.5.1 Boron deficiency

It is one of the most common deficiencies in both young and older trees. Boron is not very mobile and so deficiency appears in the young leaves. The main symptom is that leaves around the terminal bud turn light green at their base and eventually fall off. Gradually, the same symptom appears to leaves near the base of the shoots, which appear dry at their edges. Later growth shows small and distorted leaves that are stunted, fragile and finally drop off. If a small piece of the stem is cut off with a sharp knife, a brown discoloration appears due to necrosis of the cambium.

Trees suffering from boron deficiency appear chlorotic from a distance and delay entering the vegetative stage. Leaves with deficiency contain less than 20 ppm boron, while those from healthy trees have more than 20 ppm (on dry basis). In full production trees, 300-500 g sodium pyroborate is added in the soil to control deficiency, while for younger trees fewer amount is used (10 g for each year of the tree from the moment of planting). For faster response, soluble sodium pyroborate can be applied by foliar fertilization or through the irrigation system

4.9.5.2 Potassium deficiency

Potassium is a mobile nutrient and thus deficiency is most clearly shown in older leaves. They present pale chlorotic patches with the appearance of “burns” (necrosis) at the leaf tips and edges. These areas of dead tissue progress from the tip to the base, and from the leaf margin towards the intervein area. The leaf tip tends to curve downwards.

Potassium deficiency diagnosis is not safe on the basis of these symptoms, and must be further confirmed by leaf analysis. Deficient leaves contain about 0.1-0.3% potassium (on dry basis), whereas the content of well-supplied leaves ranges from 0.4 –1.7%.

Many times, potassium deficiency is due to low soil moisture (drought); potassium is adsorbed by clay and thus trees cannot take it from the soil. The problem can be relieved by selecting cultivating techniques that enhance the growth of the root system and ensure adequate soil moisture. In this case larger amounts of fertilizer are added, usually 10-15 kg of potassium per tree. Alternatively, half of the above mentioned amount can be added in the winter in the form of potassium sulfate, and the remaining amount in the form of potassium nitrate through the irrigation system. Potassium nitrate is applied through the irrigation system at a dose of 300-500 g/tree after fruit-setting.

4.9.5.3 Calcium and Magnesium deficiencies

The main symptoms of calcium deficiency is the chlorosis of the top part of the leaves, like in boron deficiency, but in this case the veins in the chlorotic area of older leaves become white. The main symptom of magnesium deficiency is the chlorosis of leaves that begins from the top or the edges of the leaf and spreads gradually in the whole leaf area. Other symptoms include severe leaf shedding and the poor vegetative cycle.

Calcium deficiency is corrected rather easily by adding 5-10 kg of calcium oxide per tree. To avoid calcium deficiency, soil pH must be determined before planting a new orchard. The amount of calcium added must be determined after soil analysis.

To correct magnesium deficiency, 300-500 g of magnesium oxide (e.g. 3.0-5.0 kg/tree potassium-magnesium sulfate, providing also potassium for simultaneous fertilization with this nutrient) are used. Alternatively, foliar sprays are applied with 2-4% soluble magnesium sulfate dilution.

4.9.6 Organic fertilizers

The use of natural organic fertilisers (manure) should be encouraged since they: i. increase the organic content of the soil and thus reducing vulnerability to erosion ii.

improve the ability for uptaking of the nutrients by the roots of the trees iii. substitute the use of the synthetic fertilizers at a significant level.

Table 14: Summary of guidelines for organic fertilizers application

Proposed actions	**Potential benefit**
Use of natural organic fertilizers such as manure or compost in soils with low organic content. In particular, addition of natural organic fertilizer in soils with content of organic matter lower than 1% (cultivations without irrigation) or 2% (cultivations with irrigation).	Maximization of yield and quality of the fruits Improvement of the characteristics of the soils (drainage, aeration, etc.) Facilitation of the growth of the root system of the trees Well-balanced growth of the trees Well-balanced uptaking of nutrients by the roots of the trees

4.10 Weed control – soil management – herbicides application

The inappropriate soil management is a major cause of soil erosion in olive farming. Changes in practice are required, even on land which is relatively flat (e.g. 3-5% slope). There are various alternative practices for reducing erosion, including contour tillage, minimum tillage (shallower and less frequent) and no-tillage. According to the experience, the frequent tillage which is widely applied is of high agronomic value. Shallower and less frequent cultivation would be equally effective as a means of controlling ground vegetation and would reduce the soil's vulnerability to erosion.

main types of pesticides that could be used Measures to increase the organic content are a very important part of good soil management, especially to reduce vulnerability to erosion. Practical measures are based on the incorporation of organic matter such as farm-yard manure, cover crops, pruning and processing residues, and on reduced tillage of the soil.

New minimum tillage and non-tillage systems have been developed which produce higher yields than conventional systems. These systems include techniques which greatly reduce erosion, particularly the maintenance of plant cover (crops such as barley or vetch, or spontaneous vegetation) on the strips of land between the lines of olive trees.

However, it is important to distinguish between the different systems. For example, the maintenance of a grass or crop cover on 30-50% of the soil area (between tree rows) has proved to be more effective in controlling erosion than "bare soil" systems based on intensive use of herbicides. In fact, no-tillage systems which involve an excessively intensive use of herbicides can expose the soil to severe erosion.

The olive tree can survive in low fertility soils under semi-arid conditions. Unfortunately, many weed species are adaptable to the same conditions and grow faster than olive trees, exercising strong competition for moisture and nutrients.

Weeds, especially perennial species, have almost the same growth pattern as olive trees. However, their adaptability and greater efficiency ensure earlier and larger growth than that of olive. For this reason, weed control must be applied four to six weeks before visible spring growth in olive trees. Table 12 presents, synoptically, the for olive tree cultivations.

Table 15: Main herbicides recommended for olive trees

Active ingredient	Remarks
Pre-emergence **Simazine** **Diuron**	**Apply 3-4 years after tree planting**
Oxyfluorfen **EPTC**	**Recommended also for young trees**
Chlorthal dimethyl	**For olive tree nurseries**
Post-emergence **Glufosinate ammonium**	**Exert slight systemic activity**
Glyphosate **Glyphosate trimensium** **Aminotriazole (amitrole)**	**Systemic herbicides**
Mixture of pre- and post-emergence **Simazine** **Simazine and aminotriazole** **Diuron and amonotriazole** **Terbuthylazine and glyphosate**	Effective on germinated weeds

Orchard floor management practices are influenced by the location, the climatic conditions, the soil characteristics, the irrigation practices, the topography of the area etc. Weeds are commonly controlled either chemically or mechanically. The area between tree rows may also be chemically treated or mechanically mowed or tilled. Alternatively, mulches, subsurface irrigation, and flamers can be used. In many cases, several weed management practices are applied in combination.

Weed control in new orchards

Trees are most sensitive to weed competition during the first few years of growth and where soil thickness is limited. Weedy orchards may require several more years to become economically productive than weed-free orchards. Regardless of the method used to control weeds, special attention must be paid not to injure trees with chemicals, or to mechanically damage the trunk or roots. As trees become established, competition from weeds is lessened as shade from the tree canopy reduces weed growth. In the following, some of the most common ways to control weeds in new orchards are presented:

Cultivation.

Some farmers prefer to manage weeds without herbicides for the first year or two after planting. This usually requires hoeing, cultivating, or using weed knives around trees several times during spring and summer, as well as cultivating or mowing between tree rows. This is best accomplished when weeds are still in the seedling stage, but it becomes more difficult when weeds are allowed to get large. Hand tools are generally used close to the tree to minimize injury from mechanical cultivators, particularly when the trees are young. Mechanical cultivators available for use in the tree row include: weed knives, spider cultivators, and rotary tillers. Rotary tillers are most effective if used on loose soil that is not rocky. Hand-held mechanical flails may be used, but can injure tree trunks. Disks, tillers, or mowers can be used between the rows. Mechanical control of weeds must be done repeatedly when weeds are immature. The equipment should be set to cut shallowly, to minimize damage to tree roots. As weeds mature, they are difficult to control, may clog equipment, and produce seed.

Cover Crops.

Planted cover crops can also be used to reduce weed populations between tree rows. With cover crops, the species selected and management will differ from one area to another. The selected cover crop should not be competitive with young olive trees. Examples of cover crops include wheat, oat, cereal rye, or barley. Cultivation in preparation for planting a winter annual cover crop will also reduce weed growth. To preserve surface cover, mow the cover crop to the correct height recommended for that crop.

Mulches.

Weeds in the tree row can also be controlled using mulches. Organic mulches (cereal straw, green waste, composted wood chips) or synthetic mulches of polyethylene, polypropylene, or polyester can be used around young trees. Also, shredded tree pruning residues could be used as a good mulch. Mulches must be applied when the soil surface is free of weeds. Mulches prevent the growth of weed seedlings by blocking light and preventing it from reaching the soil surface. They create more uniform moisture conditions, which in turn promote young tree growth. Mulches do not control perennial weed growth unless all light can be excluded. Some woven fabric mulches offer excellent weed control for several years, but the initial cost of purchase and installation is high.

Herbicides.

To control weeds with herbicides after trees are planted and before fruiting, apply a pre-emergence herbicide to either a square or circle around each tree or as a band down the tree row. Herbicides can also be applied to control weeds after they emerge. Selective herbicides are available for annual grass control and suppression of perennial grasses. The non-selective herbicide glyphosate can control broadleaf weeds after emergence, but it should be used only around mature trees with brown bark and should not be allowed to contact tree leaves.

Weed control in established orchards

Established trees (3 to 4 years after planting, under normal growing conditions) are more tolerant to many herbicides than newly planted trees, increasing thus the options available for weed control. Generally weeds are controlled between tree rows by discing or mowing and a basal treatment of herbicide is applied around each tree or in a strip application down the tree row. In the following, some of the most common ways to control weeds in established orchards are presented:

Cultivation.

Cultivation can be used in established orchards to control annual and biennial weeds and seedlings of perennial weeds. Cultivation also cuts and damages the roots of trees, reducing the ability of the tree to take up nutrients and allowing access to the tree of soil pathogens. For this reason, special attention must be given when this method is applied for weed control.

Mulches.

Mulches can also be used for weed control but they must be replenished regularly due to degradation. Degraded mulches become a perfect growth medium for weed species.

Herbicides.

Pre-emergence herbicides can be applied either alone, in combinations of herbicides in autumn after harvest, split into two applications (autumn and spring), or in winter with a post-emergence (foliar) herbicide. It may be most beneficial to delay the pre-emergent application in winter until most weeds have germinated. Afterwards, a post-emergence herbicide can be used. This allows longer weed control during the summer and does not allow much competition from weeds to the tree. For greatest safety, direct herbicide sprays only at the soil or at weed foliage, not at the tree leaves.

Table 16: Summary of guidelines for weed control and herbicides application

Proposed actions	**Potential benefit**
The presence of this nutrient is common in the soil and phosphate fertilization is not really necessary in the following cases: i. in olive orchards where high quantities of phosphate fertilizers have been used in the previous years ii. in olive orchards, in which only small amounts of phosphate must added due to low soil humidity. On the contrary, phosphate fertilization can be necessary: i. in acidic soils ii. soils containing high amounts of calcium carbonate iii. for orchards planted in shallow, infertile soils iv. in new irrigated olive orchards (1-10 years old) in which ample nitrogen is used every year. Phosphate deficiency must be determined by leaf analysis. Phosphate addition is necessary when the concentration of the nutrient in the leaves ranges from 0.09-0.10 % in the winter and the ratio N/P is around 20. Higher concentrations in the leaves or higher N/P ratios indicate that phosphate fertilization must be applied. When phosphate fertilization is necessary, it should not exceed 1/3-1/5 of the amount of nitrogen added. In particular, if 1 kg N/tree (i.e. 5 kg ammonium sulfate) is added, the corresponding amount of phosphate should not exceed 200-350 g P_2O_5/tree (i.e. 1.0-1.7 kg 0-20-0). It is suggested to add 500 g P_2O_5/tree (i.e. 2.5 kg 0-20-0) in a two-year period. In the case of severe phosphate deficiency, an amount of 4-5 kg P_2O_5/tree (i.e. 20-25 kg 0-20-0) is added in trees at the stage of full production. For younger trees, lower quantities (1-8 kg 0-20-0) are added, depending on the age and the development stage of the trees.	These fertilizers make the soil slightly more acidic and can be used in soils with alkaline pH level for pH adjustment . Rational use of fertilizers results in well-balanced growth of the trees and the fruits The soil has appropriate amount of nutrients that are available for the root system of the trees The roots of the trees uptake the amount of nutrients in a well-balance and gradual way. By applying a rational use of fertilizers (avoidance of using of fertilizers in excess) fertilizers residues do not remain in the soil. As a result: i. Surface run-off of rainfall water polluted with phosphorus compounds is avoided ii. leaching of polluted water to the underground water is eliminated iii. pollution of surface water is avoided iv. the phenomenon of the eutrophication is eliminated

4.11 Pesticides application

The major insects of olive trees are the olive fruit fly (*Bactrocera oleae*), the olive-kernel borer or olive moth (*Prays oleae*) and the black scale (*Saissetia oleae*). Although *Bactrocera oleae* is considered the most serious insect, all three are widely distributed in the Mediterranean region and occur on olives at population densities causing important economic losses.

Of the less important insect pests, some occur in particular areas or conditions at population levels that cause serious damage, e.g. *Euphyllura olivina, Zeuzera pyrina, Aspidiotus nerii, Resseliella oleisuga*. Others, although occurring only occasionally, cause serious problems by disrupting the biological balance of the ecosystem, e.g. *Parlatoria oleae, Leucaspis riccae, Philippia follicularis*.

***Bactrocera (Dacus) oleae* (Diptera: Tephritidae)**

It can be found in all Mediterranean olive-growing countries. In southern Italy, Spain and central Greece, infestations start in June-July, but after the development of the first generation, the population decreases due to high summer temperatures (exceeding 33°C) coupled with low relative humidity. Populations begin to increase again from September until November-December. In the southernmost distribution areas of olives trees, such as Crete, Cyprus and North Africa, infestations begin by the end of May.

Adults are able to live for several months. The maximum longevity is found in adults that emerge in autumn, increasing from September to November. They can survive for a short time at temperatures slightly below 0°C, but they die if they stay for days under these conditions. Temperatures from 0 - 5°C are tolerated for about a month by some individuals, but the mortality rate is generally high.

In the olive tree itself, most Bactrocera oleae are seen flying within the canopy, since this is the location where olive fruits can be found. However, the olive fruit fly has the potential of long-distance dispersal. Displacements of 4 to 10 km have been observed in the field, depending on climatic conditions, topography and olive fruit availability. Under normal environmental conditions, however, the movements are of short range.

The insect spends the winter in the pupal stage several cm below the soil and leaf litter. Under summer conditions, a preoviposition period of six to ten days elapses before mating, with longer time required earlier when temperatures are not as high.

During the preoviposition period the female is maturing the ovary and a first set of eggs. Beginning in June females actively seek and oviposit in early maturing olive fruits. From 10 to 12 eggs may be laid daily, usually one per olive fruit, and about 200 to 250 are laid in a lifetime. The female punctures the fruit with the ovipositor and deposits an egg beneath the skin. The legless larva (maggot) feeds upon the fruit tissue, causing the fruit to drop off the tree.

Duration of the life cycle varies from one to six or seven months. Male flies produce an auditory stimulatory sound or signal during courtship. Courtship and mating occur at dusk, near the end of the daylight period. Females of the olive fruit fly produce a multi-component pheromone, and are the only tephritid females known to produce a pheromone; males produce the pheromone in other tephritids that have been studied. The major component of the pheromone is 1,7-dioxaspiro[5.5]undecane and it is a relatively long-range attractant for males. Male flies also produce this compound, and attract males, but females are not attracted to the compound from either sex.

Insect control management includes bait sprays, trapping of adult flies, harvest timing, fruit sanitation after harvest, and biological control. Additionally, insecticides are used in bait-sprays or as sprays from the air to control the olive fruit fly.

More environmentally friendly techniques that are being tested or used in limited areas use sterilized males by radiation and pheromones. Both sexes can be sterilized with 8 to 12 krad (80 to 120 Gy radiation), when late pupae are exposed to this level of irradiation. Synthesis of 1,5,7-trioxaspiro[5.5]undecane, an analogue of the major pheromone component, has been synthesized and tested, and under optimal conditions it was as attractive as the natural compound, but it did not last as long in traps as the natural material. Small plywood rectangles dipped in 0.1% aqueous solution of deltamethrin for 15 minutes and added to bait stations containing either sex pheromone or ammonium bicarbonate, a food attractant, gave cost-effective control in a large test orchard.

Prays oleae (Lepidoptera: Hyponomeutidae)

The olive-kernel borer or olive moth seems to have had the same origin as the olive tree. It was known as a pest of the olive in very early times, as is evident from descriptions in ancient Greek and Roman documents. Prays oleae exists in all Mediterranean olive-growing countries.

Prays oleae feeds and develops on olive flowers, fruits and leaves. Its yearly life cycle comprises three distinct generations. The first larval generation leaves on floral buds causing light to moderate flower damage. The second generation appears in the stone of the olive fruit where it eats the kernel. This is the most troublesome stage since it can cause significant fruit drop and damages the fruit for canning and oil making. Olive Oil affected by the moth will have an oxidized and rancid taste.

The third generation leaves on leaves and young shoots. Larvae are leaf miners that use silk to roll the leaf into a protective shape. The leaf larvae can live for months during the autumn and winter months, with the pupae over wintering on the leaf or bark to start the cycle over. In Southern Mediterranean regions, moths start emerging in early March, peaking in April and ending at about the beginning of May. The moths have twilight and nocturnal habits. They usually stay still on the lower surfaces of the leaves during the day and start to be active at twilight.

Climatic conditions greatly affect the occurrence of *Prays oleae*. Eggs and newly hatched larvae are especially vulnerable in conditions of low relative humidity and high temperatures. With a relative humidity of less than 60%, eggs dry out within a few hours regardless of temperature. In the case of newly hatched larvae, they do not survive at temperatures above 30°C. This can explain why *P. oleae* is relatively scarce in hot and dry continental zones.

Control of first generation olive moths can be done using biological insecticides based on *Bacillus thuringiensis* (e.g. Thuricide, Bactospeine). Second generation individuals must be sprayed with selective insecticides such as triflumuron (Alsystin) and teflubenzuron (Nomolt) that suppress chitin synthesis. Other conventional insecticides comprise fenthion (Lebaycid), methidathion (Ultracide), dimethoate, etc.

Saissetia oleae (Homoptera: Coccidae)

The olive tree is one of a large number of host plants on which ***Saissetia*** *oleae* has been found. In general, it completes one generation per year in the Mediterranean although, in some areas and under favourable conditions, a second autumn generation may develop. The preferred habitat is the lower surfaces of olive trees. *S. oleae* damages the olive tree directly by sucking the sap, and indirectly by releasing honeydew onto the leaves. This honeydew is a substrate for the development of different fungi and is thus responsible for the spread of a sooty mould. By coating the leaves, this sooty mould impedes photosynthesis and respiration and finally induces more or less serious leaf drop.

Adult females are dark brown or black with a prominent H-shaped ridge on the back. Young scales are yellow to orange crawlers and are found on leaves and twigs of trees. High relative humidity and mild seasonal temperatures tend to favour *S. oleae*. For this reason, the density of the olive tree canopy and microclimatic conditions beneath it, related to cultural practices (grove density, soil depth, presence of water, fertilizers, pruning, etc.) have an important influence on scale development. In addition, moderate use of nitrogen fertilizers and irrigation helps to avoid the increase of amino acid and sap circulation within the tree, which would otherwise provide a rich nutrient substrate for *S. oleae* development.

Pruning to provide open, airy trees discourages black scale infestation and is preferred comparing to chemical treatment. In addition, biological control is effective, since a number of natural enemies, including both parasites and predators attack black scale. The most frequently encountered parasites are the native *Metaphycus flavus* and the exotic *Metaphycus helvolus and M. bartletti.* Regarding predators, the most frequently found is *Scutellista cyanea* that is an egg predator. These parasites, combined with proper pruning, provide sufficient control in northern and coastal orchards. In other regions, biological control is often ineffective because black scale's development pattern hampers parasite establishment.

In the cases when the use of chemical herbicides is necessary, and according to the following criteria:

- Toxicity to human
- Toxicity to natural enemies
- Toxicity to other natural organisms
- Potentiality to contaminate surface and underground waters
- Selectivity
- Residues level
- Absorbance level by the soil
- Range of information on the characteristics of the chemical

Some pesticides is not allowed to be used while other ones can be used under specific conditions. In particular:

Not allowed chemicals:

- Synthetic pyrethrines in spaying applications: These chemicals should be used only in the form of i. attractant traps ii. proteinaceous or/and feromonic baits.
- Chemicals with high toxicity and high resistance level to degradation: Diquat and Paraquat

Allowed under conditions:

- Organophosphates
- Fungicides with high level of resistance to biodegradation

The selection of the tools as well as the conditions of the application of the pesticides must be based on two main parameters: i. elimination of the potential hazard to the user ii. avoidance or minimization of the pollution to the air.

Table 17: Summary of guidelines for pesticides applic**ation**

Proposed actions	**Potential benefit**
Pruning to provide open, airy trees Application of pesticides under windy conditions are not allowed Pre-calculation of the quantity of chemical that is required for the application, according to the size of the trees Punctual applications using proteins or/and	Rational input of pesticides to the plantations Elimination of the pesticides residues in the leaves and the fruits Saving of money from avoiding of using of pesticides in excess

pheromones against olive fly Calibration of the apparatus before the application Maintenance of the apparatus every four years (at least) by certified personnel. Use of apparatus with incorporated system for adjustment of the flow of pesticide Biological and other control methods with a reduced environmental impact (masstrapping of olive fly and biological control of Prays with Bacillus thurigiensis) should be applied. Aerial spraying (applications using airplanes or helicopters) is not allowed Synthetic pyrethrines should be used only in the form of i. attractant traps ii. proteinaceous or/and feromonic baits. Chemicals with high toxicity and high resistance level to degradation (e.g. Diquat and Paraquat) should be avoided	

4.12 Diseases

The most important olive tree diseases are verticillium wilt, olive knot, leaf spot and fruit mummification. In the following text, suggestions for the prevention or minimization of these diseases are given.

Verticillium wilt

The disease is caused by the fungus *Verticillium dahliae*. The fungus can survive in the soil for years embedded in infected tissues or in the form of sclerotia. It is spread by soil movements during tillage, irrigation water and infected tools used for pruning. Symptoms of the disease appear when leaves on one or more branches of the tree suddenly wilt early in the growing season; this process intensifies as the season progresses. Death of mature trees infected with Verticillium is also possible. Darkening of xylem tissue, a key symptom for distinguishing Verticillium wilt in many crops, is frequently not apparent in olives.

The most effective management strategies to protect trees from Verticillium wilt are those taken before planting. When considering a new site for an olive orchard, it is not recommended to use land that has been planted for a number of years with crops that are highly susceptible to the disease, such as cotton, eggplant, peppers, potato, or tomato.

Inoculum levels can be reduced before planting by soil fumigation, soil solarization, flooding the fields during summer, growing several seasons of grass cover crops or a combination of these treatments. A resistant rootstock is not available, although some tolerance has been reported in the cultivar Ascolano.

In established orchards, no reliable method of control has been developed. Soil fumigation and soil solarization have provided inconsistent control in these cases.

Olive knot

This is the only bacterial disease of the olive tree. It is caused by *Pseudomonas syringae* pv *savastanoi*. On infected parts of the tree (mainly primary and secondary branches) irregularly shaped proliferations (knots) develop. Bacteria are transmitted by way of tree wounds resulting from harvesting practices. Within the host plant, the bacterium synthesises indoleacetic acid inducing cell proliferation and tumour formation. There are various strains of the bacterium differing from each other to virulence. Various olive cultivars show different degrees of sensitivity to *P. savastanoi*.

In general, older branches and trees are more corruptible to the disease. Attention must be paid to cultural practices as the pruning and destroying of infected plant material and the use of harvesting methods that do not harm the tree. Treatments with fungicides based on copper may reduce the disease but do not eliminate the bacterial population, which soon multiplies back to previous levels. It is also important to cover wounds after pruning such as galls on limbs or trunks with Bordeaux mixture.

Leaf spot

This disease is caused by the fungus *Cycloconium oleaginum* which is found in all Mediterranean countries and in California. It is pathogenic only to the cultivated olive tree. Although it is of minor importance in arid and hot regions, irrigated olive orchards as well as areas with high relative humidity are highly susceptible. Infectious conidia can survive throughout the year with peak periods in October-November and March-April. The pathogen is scarce during the summer months.

Dispersion takes place mainly by rainfall, since germination of conidia occurs only when enough water is available. Leaf spot causes the leaves to appear slightly chlorotic (some varieties show more chlorosis than others). The undersides of some leaves become discoloured with the conidial stage of the fungus, which appear to be covered with black dust. These leaves may fall, causing some defoliation in some cases. Fruit can also develop small, brown lesion spots and not mature uniformly.

Infections developing between late November and February do not show any symptoms until early spring when lesions appear, producing spores in abundance. The high susceptibility of the olive tree to infection in spring is explained by both the increased availability of inoculum and by the rainfall. Under the normal temperatures of this season, lesions appear within a few weeks.

Measures for control of the disease include cultural practices (such as selective pruning to reduce relative humidity within the tree canopy) and treatment with protective fungicides (e.g. Bordeaux mixture) at the beginning of autumn before the first infection occurs, or in the early spring. In addition, highly susceptible olive tree cultivars to the disease must be avoided (e.g. Manzanilla, Frantoio, Arbequina, Moroccan Picholine).

Fruit mummification

This disease is caused by the fungus *Gleosporium olivarum*. The fungus can penetrate healthy fruit skin, although existing lesions may facilitate the process. Infected fruits display brownish round spots, which expand in size. Usually, infection begins at the distal end of the olive fruit, where water droplets rest after dew or rainfall. Dissemination of the inoculum is facilitated by rain, since germination occurs only in the presence of water. Fungal conidia may survive for one year in mummified fruit at low temperatures.

The disease is common in Mediterranean olive-growing countries, particularly in Portugal, Greece and Lebanon. First attacks appear in September while olive fruits are still green. The combination of rainfall and high relative humidity results in the development of pouches and conidia on the infected fruits creating secondary infections that lead to fruit drop and increase in acidity of the extracted olive oil. Occasionally, the infection may also spread to vegetal parts causing leaf drop, shoot death and the overall weakening of the infected tree. For the control of the disease, preventive fungicide treatment is recommended at the beginning of September before the rainy period. Application must be repeated later if secondary infections are noticed.

Table 18: Summary of guidelines for elimination of diseases

Proposed actions	**Potential benefit**
Verticillium wilt : Actions must taken before planting: When considering a new site for an olive orchard, it is not suggested to use land that has been planted for a number of years with crops that are highly susceptible to this disease, (such as cotton, potato, tomato etc.). Inoculum levels can be reduced before planting by soil fumigation, soil solarization, flooding the fields during summer, growing several seasons of grass cover crops or a combination of these treatments. In established orchards, no reliable method of control has been developed. Soil fumigation and soil solarization are inadequate in these cases. Olive knot: Attention must be given to practices as the pruning and destroying of infected plant material and the use of harvesting methods that do not harm the tree. Treatments with fungicides based on copper may reduce the disease but do not eliminate the bacterial population, which soon multiplies back to previous levels. It is also important to cover wounds after pruning such as galls on limbs or trunks with Bordeaux mixture. Leaf spot: Measures for control of the disease include cultural practices (such as selective pruning to reduce relative humidity within the tree canopy) and treatment with protective fungicides (e.g. Bordeaux mixture) at the beginning of autumn before the first infection occurs, or in the early spring. Highly susceptible olive tree cultivars to the disease must be avoided (e.g. Manzanilla, Frantoio, Arbequina). Fruit mummification: For the control of the disease, preventive fungicide treatment is recommended at the beginning of September before the rainy period. Application must be repeated later if secondary infections are noticed.	Well –balanced growth of olive trees Satisfactory yield of olive fruits Ensuring of the quality of the olive fruits

4.13 Biodiversity and landscape conservation

Biodiversity is a key parameter for maintaining the “ecological infrastructure” of the olive plantation. This infrastructure is made up of elements such as patches of natural and semi-natural vegetation, hedges, dry-stone walls, wet areas and old trees. The elimination of such features has become common practice in many areas, as part of a general process of rationalisation and intensification of farm management. The maintenance or restoration of these ecological features could be promoted in order to increase the natural value of olive plantations. At the same time, these features often contribute to landscape value and, in the case of terraces, stone walls and patches of vegetation, play an important role in reducing soil erosion.

4.14 Fruit harvest

Olive fruit harvest is usually carried out manually or mechanically. The traditional manual system consists of knocking the branches with long poles of wood. The olives fall on synthetic nets extended around the trees and then picked directly from the ground. This method is not recommended as both olives, with consequent oil production of very bad quality, and branches, particularly young shoots, are damaged.

Another method is the so-called “natural drop”, in which the fruits are harvested directly from the ground after their natural fall on nets. This method is preferred when the trees are of remarkable height and there is little labour availability. The fruits are harvested gradually (at least once every two weeks), otherwise the quality of olive oil is greatly reduced. Another disadvantage is the prolonged harvest period (3-5 months). The above methods have been replaced by the manual “milking” of the branches, drawing the fruits out and leaving them to fall into small baskets, which are suspended from workers at waist level. This method is very good at avoiding fruit injury but presents the drawback of high labour costs. Manual harvest can be improved using hand held pneumatic combs. They consist of a pneumatic comb assembled on variable length telescopic rods (from 2.50 m to 3 m).

Rake teeth in two sizes facilitate penetration into the crown of the tree and detachment of the fruits. The system operates by a compressor that is applied to the three points of a tractor or to a motor cultivator. The combining action of the fingers harvests without damaging the fruits or trees.

A variation of this kind of picking machine is the hand-held pneumatic shaker. The shaker is attached to a standard compressor unit, as used for spraying. A hook attaches to large limbs and shakes the olives loose, similar to the combs above.

Mechanical harvesting systems have considerable economic advantages compared with traditional manual picking procedures, mainly due to great reduction in labour costs and harvesting time. The most common mechanical picker is the tractor-mounted shaker. The shaker is attached to a 70-80 HP tractor and utilizes a hydraulic pump to transfer power to the vibrating head. Harvesting nets are first placed under the tree.

The shakers are hooked to the plants by different types and forms of pliers or rubber rolls and they engrave to the plants and to the fruits pendulum-like or rotary movements. The movements are brief and violent, so much that the drupes are easily detached from the trees and fall in underlying nets.

Table 19: Summary of guidelines for harvesting

Proposed actions	**Potential benefit**
The traditional manual method consists of knocking the branches with long poles of wood, falling of the olives on synthetic nets and then picking directly from the ground is not recommended as olives and young branches are damaged. Also, the quality of the produced olive oil is not good. The method of "natural drop", in which the fruits are harvested directly from the ground after their natural fall on nets is preferred when the trees are of remarkable height and there is little labour availability. The fruits are harvested gradually (at least once every two weeks), otherwise the quality of olive oil is greatly reduced. The above methods have been replaced by the manual "milking" of the branches, drawing the fruits out and leaving them to fall into small baskets, which are suspended from workers at waist level. This method has the advantage of avoiding fruit injury but presents the drawback of high labour costs. Manual harvest can be improved using hand held pneumatic combs. They consist of a pneumatic comb assembled on variable length telescopic rods (from 2.5 to 3 m). Rake teeth in two sizes facilitate penetration into the crown of the tree and detachment of the fruits. The system operates by a compressor that is applied to the three points of a tractor or to a motor cultivator. The combining action of the fingers harvests without damaging the fruits or trees. Mechanical harvesting systems have considerable economic advantages	Avoidance of damage on branches of the trees and injury of olive fruits Production of olive oil of a high quality Applying mechanical harvesting, reduction in labor costs and harvesting time is obtained.

compared with traditional manual picking procedures, mainly due to great reduction in labour costs and harvesting time. The most common mechanical picker is the tractor-mounted shaker. The shaker is attached to a 70-80 HP tractor and utilizes a hydraulic pump to transfer power to the vibrating head. Harvesting nets are first placed under the tree.	

4.15 Information and training

The case studies stress the need to providing effective information, advice and training to olive farmers on environmentally beneficial – ecological practices. Currently this only occurs on an extremely limited scale.

An effective mean for advising the olive trees farmers is the employment of a technical adviser by the farmer associations in each area (with financial aid from the government). By creating a much more direct link between the farmers and a specialist adviser, this system may be more effective than conventional farm advisory services.

Also, special information campaigns and training courses should be held by the farmer associations in collaboration with agricultural institutes, research centers and Universities in order to promote the awareness of the farmers and to train them on viable ecological and environmental friendly methods and practices.

The content of the dissemination campaigns and of the training courses must be adapted to:

- Age and level of education of the farmers
- Main employment of the farmers (full - time or part – time olive tree farmers)
- Size of olive tree farms
- Years that the farmers deal with the olive tree farming
- Existing awareness and interesting level of the farmers in environmental issues
- Current mode of getting information (personal observations and experience, advising by agriculturalist etc.)

4.16 Conclusions – recommendation for policy initiatives

Based on the overall conclusions for the interpretation, previous environmental studies, ECOIL results and many other papers, it is argued that drastic changes are needed to obtain the environmental cultivation of olive fruit.

Environmental Impact studies are performed to analyse and correct actual imbalances but they also show how fragile the actual equilibrium is and what can happen in the future. Most ecological practices and recommendations refer to the long term, due to several problems, i.e. nature time scale, human willingness to change and ethical values.

For example, olive grove soil erosion is a human scale irreversible process. It takes almost 80.000 years to produce a fertile soil and it can be absolutely destroyed and annihilated in less than one century. What is the economical cost of it?

Environmental systems and recommendations are definitely important when reducing environmental impact. However, nowadays degradation rates and significant impacts do not allow to follow a leisurely change without taking into environmental and societal problems.

Thus, short term or immediate solutions have been exposed in previous sections. These fixings permit to improve many aspects and gain some time, but are not absolutely long time sustainable measures. Mind procedures and hanging are not only made by consciousness-raising but also from acquisition of habits: these are medium and long term changes. Thus recommendations are proposed in different time horizons: short, medium and long term. We have not proposed any dates because frame time depends of willingness of administrations (European, National and Local Level) to apply those proposals and complexity of social changes and unexpected duration of different stages.

All process involved in oil production and oil consumption must be taken into account. Despite the fact that Oil Mills (Industrial Phase) impact in LCA is not so important in the whole olive oil production cycle, its collaboration in the whole integral cycle is of capital importance as it is the one who can process or help to process pomace and avoid the huge use of chemical fertilizers. The "life cycle thinking" is useful for establishing environmental impacts among different phases but also, an approach of "life cycle consequences" should be developed.

The following example seeks to illustrate the aforementioned statements.

Burning pruning residues has a negative environmental impact. But, what can be done with pruning waste? An idea is to separate browse and leaves from the firewood, chopping the first one adding organic matter to the soil and the second one, used as biofuel. To chop biomass a machine is required, that costs money, and probably will have an important[①] environmental impact. Furthermore, there is need to transport firewood to where it is burnt or transformed in pellets or other energy carrier and thus, there is need for more energy and more machinery for this transformation. Furthermore, farmers showed concern about olive bark beetle when chopping pruning residues. It is proved that firewood piles attract olive bark beetle and after being for some months in the field, just a match will burn the two problems and avoid the use of Dimethoate to control the pest. What is ecologically sound? What is economically viable? What is socially feasible?

It is always better to follow a precautionary and preventive approach than a secure and curative one, which is unfortunately, until now, the most common one.

In terms of agriculture there should be a change between Assisted Agriculture and Knowledge Intensive Agriculture (Abudi, 2001; Naredo, 2002)[②]. Some authors argue that change should be gradual whereas other evoke for a radical change. In fact, agricultural and nature management needs a radical change of resources but a change without

[①] ECOINVENT database gives a value of about 30% of overall environmental impact of machinery in agricultural processes.

[②] In Sánchez de Puerta (2004)

interiorising why only drive us to failure. A change of values, of living attitudes and human needs is urgent but this should be done with a interiorisation of the problem of, making recommendations by one self

But, how to change the today's model? A change for money is a short time term change and most farmers change because of money, but not because of personal beliefs. Many of them have a fully understanding of the forthcoming consequences of actual economical system, while others ignore or take a more individual perspective. In all cases, farmers must live from their works and actual economic profit of agriculture is low in most cases (except big owners and corporative industries and greenhouses) compared to other jobs.

According to the project conclusion the most important impacts come not from real agricultural practices, but from industry and post-green revolutions ones : use of chemical agroinputs and machinery, distribution of inputs through a global scale systems, etc

It is broadly accepted that adoption of agri-environmental measures is low. There has not been feasible to look for its implementation in our case study area, but everything points out that follow the overall pattern. Sánchez de Puerta (2005) carry one of the few qualitative environmental studies about adoption on Agri-environmental measures. Many times farmers agreed that even its implementation is useless or they are not well adapted or developed by external researchers, that obviously, do not take into account all possible variables when developing them.

Compensatory payments are carried by CAP, trying to fix market failures but they are clumsy because environmental pollution and degradation and social problems are not the problem itself, are huge consequences made of small sum of individual consequences because of macroeconomical approach and capital movement.

European Agriculture is drowned by politic, market and society in form of consumers than demand more and more quality an environmental protection everyday and want to have it as cheap as possible. Food prices and purchasing power are totally imbalanced. Food is not for playing neither in plate nor fields or orchards… it is a basic human need. Most people have lost their common sense when referring to food production: it is not common anymore knowing where does the food come from and how much effort it is needed, and thus, common sense cannot exists. It is impossible appreciate and give real value to something that is unknown.

As previously explained, proposals or recommendations will be made in different time horizons.

4.16.1 Short term

- Follow ITGA recommendations and guidelines referring to olive tree cultivation
- Avoid use of chemical inputs
- Take seriously the problem of soil erosion
- Plan training activities based in actual general guidelines in olive tree cultivation as a first step of environmental awareness.

4.16.2 Medium term

Organic farming

The adoption of organic farming may be the solution of the near future. There is a difference from organic farming regulated by 2092/91 and real organic farming. For many researchers and farmers, changing from conventional to organic farming is just a substitution of inputs. But that is obviously, not true.

Regulated organic farming has often, less environmental impacts than the conventional one, but this is not true in all situations as some research have been able to contrast including in LCA. A real ecological agriculture is that one which can provides food and other goods having an acceptable environmental impact: preserving soil, flora and fauna as much as possible and closing the loop with local distributions and nutrient cycling.

Table 20: Comparisons of types of organic farming

Issue	***Real Ecological Agriculture***	***Conventional Agriculture***
Knowledge	Intense in Knowledge, trial and error	Low, receipts
Knowledge Source	Transdisciplinary technical - social and local knowledge	Multidisciplinary agronomic approach
Inputs	Maximizing self sustainability	Total dependency of exterior
Production of goods	Market (global) independent	Market (global) dependent
Destiny of Outputs	Local markets	Global Market
Farmers decisions	High importance	Low importance

Management of on-field waste

Pruning residues are a potential source of energy and soil organic matter. Field work must be done to separate firewood and browse and leaves.

Firewood can be used directly or in form of pellets to obtain electricity or heat for the oil mill in a short term. In a medium-long term horizon, it must be converted to gas because of storage problems. All this initiatives must be further studied.

Chopping browse and leaves will add soil organic matter and nutrients to the soil, which combined with compost will provided an optimal soil condition in all senses: structure, nutrients and avoid soil erosion. However, this activities are energy and machinery dependent and a previous evaluation of them must be made in order to obtain reliability and efficiency of this changes.

Contact with people developing some such practices in a local or national scale must be done for guide these changes.

Local Good Agrarian Practices

Based in a multidisciplinary, participatory and horizontal approach, all local actors involved in olive oil production, Oil mills, technicians, farmers and rest of society (consumers), must achieve a consensus to generate good agrarian practices. Thus, self generated agrarian and oil extraction practices will be accepted by majority of actors involved. Maybe, at this point, these changes will generate a self-sustainable region in many aspects and support from the EU will not be needed. However, this is too perfect to be true, but, at least, self-generated good agrarian practices can be sent to European Commission in order to receive its approval and maximize number of farmers that will ensure environmental commitments.

4.16.3 Long term

Agrarian co-operation

Promote corporatism of farmers to share machinery and other goods. Many changes proposed are not viable when farmers buy their own machinery but profitable when farmers share it.

Also, union of farmers can get better results that from an individualist perspective. Sharing tasks help people make driving in a same direction, with environmental and social shared benefits.

Local Economy: Local consumption vs. distribution of goods

Local production of goods allows consumer to have a closer contact to farmers and easily trace back through production chain. Furthermore, money remains for local and rural economies, usually exporting nutrients in form of food at considerably low prices –and that haven't change to much since a long time- and buying everyday more expensive chemical inputs. Added value for produced goods remains in area, allowing people carrying several activities to satisfy population needs.

This will lead to minimize environmental impacts, promote local good quality foodstuffs and enhance local investment.

4.16.4 Other policy initiatives

The following section indicates the basic policy initiatives that are recommended in order to promote the sustainable and environmental friendly cultivation of olives. These proposals are based on the general concepts that derived from the analysis of the life cycle of the olive oil production and particularly the cultivation of olives:

- Subsidies that are based on olive or olive oil production lead to intensification and expansion, which result in negative impacts to the environment. The CAP olive regime favors the development of intensified cultivations, because the subsidies are paid in direct proportion to production and intensive plantations can produce 10-20 times more olives per hectare than low-input plantations (and consequently, they receive 10-20 times more financial support). Yet, intensive plantations need far less support than low-input plantations, because they are inherently more competitive. Furthermore, traditional, low-input farms have higher labour costs than intensive plantations, due to factors such as the presence of terraces and old, awkwardly shaped trees, which constitute part of the environmental value of traditional plantations. Under the existing regime, many low-input plantations are barely viable, and only continue to be managed thanks to family or casual labour, either unpaid or very poorly remunerated. This current subsidy based on the production should be changed into a payment that: i. is based on cultivated areas ii. is unconnected to the production level iii. has a flat-rate payment per hectare, not related to historic olive plantations. The use of a flat-rate area payment would provide a more solid basis for the viability of low-input plantations in marginal areas, through a higher and more consistent level of aid reflecting the high labour costs of these production systems. Replacement of production subsidies that are given to olive tree farmers with a flat-rate area payment unrelated to production or yield, could remove the incentive for intensification and increase the support for low-input, marginal plantations.

- Until now, farmers have received CAP subsidies regardless of whether they protect or degrade the environment. Farmers should be required to comply with a basic standard of environmental responsibility in return for the public support they receive, an approach known as “cross-compliance”. This could be achieved by requiring of compliance with regional codes of Good Agricultural Practice. These codes should incorporate basic environmental protection and be developed with full participation of farmers organizations, environmental authorities, NGOs and other stakeholders. National and regional authorities should require olive farmers receiving CAP support to comply with locally-established codes of good agricultural practice incorporating basic environmental protection, within the framework of Article 3 of Regulation 1259/1999. This “cross-compliance” measure would aim to prevent basic inefficient practices, such as: excessive tillage, tillage up and down slopes, bare soil at critical times of the year, illegal water extraction (illegal boreholes, extraction above legal limits), illegal clearance of natural habitants, persecution of protected wildlife species, irrational agro-chemicals use. In the USA, for example, farmers cultivating land with a high erosion risk are required to draw up a soil conservation plan measures in return for the farm subsidies they receive.

Of the 59 million hectares identified as highly erodible at the start of the programme in the mid-1980s, conservation plans had been approved on 57 million hectares and fully applied on 34 million hectares by the early 1990s. A similar approach is required to help address soil erosion and other environmental problems in olive farming.

- Inclusion of environmental data and information in the GIS data-base, based on aerial surveys, that is being developed by the EU in order to manage the olive support regime. By this way, a combination of agronomic and environmental data in one cartographic information system will be achieved. The inclusion of data such as slope of plantations, vulnerability to erosion, state of underground and surface waters (pollution and exploitation levels), presence of terraces, location of natural habitants etc., would allow the targeting of policy measures at national and European level for environmental objectives. This would support significantly towards environmental integration in agricultural policy making and would facilitate a more effective implementation of EU and national environmental law, such as the Water Framework Directive, the Nitrates Directive and Habitats and Birds Directive.

- Comprehensive agri – environment schemes for olive farming should be designed and implemented by the national and regional competent Authorities to address the full range of environmental issues in the country, region or area, promoting specific practices. All actions rewarded should go beyond Good Agricultural Practice while clear and quantified objectives should be established for these schemes as well as effective monitoring systems to check whether targets are achieved. These schemes should include the maintenance and restoration of terraces and wildlife habitats and the use of sheep grazing for weed control, as well as more standardised systems, such as organic production.

- Programmes to implement sustainability strategies for olive farming should be developed by the competent Authorities, including targeted funding/subside for:
    - Associations of farmers who employ a technical advisor for developing and pursuing more sustainable practices.
    - Grant-aid for investments in environmental improvements (e.g. machinery for changing to non- tillage systems).
    - Economic diversification, improved production quality and labelling schemes incorporating environmental criteria.

- The case studies stress the need to providing effective information, advice and training to olive farmers on environmentally beneficial – ecological practices. Currently this only occurs on an extremely limited scale. An effective mean for advising the olive trees farmers is the employment of a technical adviser by the farmer associations in each area (with financial aid from the government). By creating a much more direct link between the farmers and a specialist adviser, this system may be more effective than conventional farm advisory services.

- Also, special information campaigns and training courses should be held by the farmers' associations in collaboration with agricultural institutes, research centers, and the competent local, regional and national Authorities in order to promote the awareness of the farmers and to train them on viable ecological and environmental friendly methods and practices. The content of the dissemination campaigns and of the training courses must be adapted to:
    - Age and level of education of the farmers
    - Main employment of the farmers (full - time or part – time olive tree farmers)
    - Size of olive tree farms
    - Years that the farmers deal with the olive tree farming
    - Existing awareness and interesting level of the farmers in environmental issues
    - Current mode of getting information (personal observations and experience, advising by agriculturalist etc.)

- A European Organisation namely Conservation Agriculture Federation (ECAF) was established by a group of European scientists, technicians and farmers interested in the transfer of technology and the adoption of conservationist practices in the agricultural sector. At present, national associations from fourteen European countries (including Spain and Greece) belong to the ECAF. It is suggested that stakeholders from Cyprus to join this Federation.

5 Project Conclusions and future research needs

5.1 Application of LCA

- It is very important to take into account infrastructure as it is very important for future comparisons between alternatives.
- The application of LCA is useful in "Ecological Economics". Chrematistics vs management of resources (Martínez Alier, 1987).
- LCA analysis allows us to perform more global than regional and local environmental impacts studies, as most pollutants have been introducing regarding to atmosphere[①] compartment. Regional and especially local environmental impacts are much site dependent because most environmental impacts rely on soil and biodiversity. For analysis of local areas, other environmental methodologies should complete this approach.
- It has been difficult to obtain information of olive tree cultivation in Ribera Baja as well as impossibility to perform exact calculations.
- LCA is a complex but valuable tool for environmental assessment

5.2 Results and Interpretation of LCA

Industrial Agriculture generates main environmental impact from those processes associated from inputs coming from Agro-industrial Inputs: production of fertilizers, pesticides as herbicides as well as on field use and emissions from technosphere.

Main environmental impact in agriculture come from intensification of production and thus, alternative agricultural systems are needed.

5.3 Proposals

Proposals range from short to long term, from applying actual partial solutions to a redesign of the system: from global economies to local ones, from conventional-intensive in technology and resources agriculture to an organic-intensive in knowledge one.

The eco-production of olive oil by farmers and oil mills must be assured by an eco-consumption of olive oil, where consumers are a key role of this change.

[①] When comparing olive tree specific environmental impact studies, atmospheric pollution is of maximum importance in LCA, whereas in AHP is the lowest contributor.

5.4 Overall conclusions and further research needs.

Drastic changes are needed to achieve a real sustainable society. Oil must be consumed in a local scale and must get a fair price for its production, avoid intermediaries between producer and consumers. This independence from the market and global scale decision will allow farmer to achieve real organic agriculture, based in agronomical and not economical criteria.

Although, consequences of a broad implementation of this principles at a local/regional levels will:

- Optimize the use of agricultural land and increasing space for natural areas
- Maximize biodiversity in both agricultural and natural lands
- Dignify agricultural tasks
- Sustain local economies
- Others

Further studies should be made comparing ecological vs. conventional agricultural production of olive oil involving complex factors as pomace processing, Biofuel production, and others.

Thus, participatory local research in farming and agro-industry is needed to implement this set of recommendations. Energy, mass (specially water) and information balances, using several environmental methodologies (LCA, Ecological Footprint and others) as well as on-farm agricultural research are key point to obtain sustainability in its broader sense.

Scientific knowledge in natural and social sciences in last decades have shown relations among different actors (humans and not humans) involved in agricultural production. It is a shame that even nowadays, a technocratic approach still been used when trying to solve environmental problems that in most cases, an they can only be solved by a social involvement.

Future sustainable management of resources will be knowledge intensive and will minimize technology use, lowering dependencies of farmers from industry.

References

1. Andrés Caraballo Roldán (2002). Sector del Olivar: Almazaras. Manual de Gestión. Junta de Andalucía.
2. Arjona R., García, A. and Ollero P. THE DRYING OF ALPEORUJO, A WASTE PRODUCT OF THE OLIVE OIL MILL INDUSTRY. Journal of Food Engineering 41 (1999) 229-234
3. Beaufoy (2000). The environmental impact of olive oil production in the European Union: Practical options for improving the environmental Impact.. Ed. European Forum on Nature Conservation and Pastoralism; Asociación para el Análisis y Reforma de la Política Agro-Rural. Brussels.

   http://ec.europa.eu/environment/agriculture/pdf/oliveoil.pdf
4. CA+E (2004) Aproximación a la medida de la ecoeficiencia en las empresas agroalimentarias de la Región de Murcia: Sector Almazaras Industriales..
5. CA+E (2004) Fichas de Definición y calculo de los indicadores de ecoeficiencia del sector de Almazaras. Región de Murcia. Consejería de Agricultura, Agua y Medioambiente. Ref 139/02 MA-ALM (Solo contiene INDICADORES).
6. Cirio U., Agrochemicals and environmental impact in olive farming, Olivae 65, International Olive oil Council, Madrid, Spain, 1997
7. EU. 2004. The Common Agricultural Policy Explained. European Communities. Available at http://europa.eu.int/comm/agriculture/publi/cap_en.pdf
8. International Organisation of Biological and Integrated Control of Noxious Animals and Plants (IOBC), Guidelines for integrated production of olives, IOBC/WPRS Bulletin Vol. 25 (4), 2002
9. International Organisation of Biological and Integrated Control of Noxious Animals and Plants (IOBC), Integrated production: Principles and technical guidelines, 2nd Edition, IOBC/WPRS Bulletin Vol. 22 (4), 1999
10. International Organisation of Biological and Integrated Control of Noxious Animals and Plants (IOBC), Integrated production in Europe: 20 years after the declaration of Ovrannaz, IOBC/WPRS Bulletin Vol. 21 (1), 1998

11. Jarabo Friedich, F. and Elortegui Escartín, N. ENERGÍAS RENOVABLES (2000). Ed. S.A.P.T., Madrid

12. JCLM (Junta de Castilla-La Mancha), 2005. Buenas Prácticas Agrarias webpage. www.jccm.es/agricul/paginas/desarrolloruralbuenaspracticas.htm

13. Kabourakis, E., Learning processes in designing and disseminating ecological olive production systems in Crete. In: M. Cerf, D. Gibbon, B. Hubert, J. Jiggins, Paine, M., Proost, Rolling, N. (eds) Cow up a tree. Knowing and learning for change in agriculture. Case studies from industrialised countries. INRA Editions, Paris, France, 2000.

14. Kabourakis, E., Vassiliou A. Designing and disseminating ecological production systems for perennials. A first step for developing sustainable organic farming systems for the Mediterranean. Proc. FAO Working Group on Organic Farming, 23-26 September 1998, FiBL Research Institute, Switzerland. REU Technical Series 53, FAO Italy, 2000

15. Kabourakis, E., Prototyping and dissemination of ecological olive production systems in cooperation with farmers. In W. Doppler, A. Koutsouris, A. (Eds.): Rural and Farming Systems Analysis: Environmental Perspectives, Proceedings of the third FSRE European Symposium March 25-27, 1998, Hohenheim. Margraf Verlag, Berlin., 2000

16. Kabourakis E., Code of practices for ecological production systems in Crete, Olivae 77, International Olive oil Council, Madrid, Spain, 1999

17. Kourouxou M., Siandros G., Iakovidou O., Kalburtji K., Olive trees farmers: Agricultural management, attitudes and behaviours towards environment, Proceedings of the 9th International Conference on Environmental Science and Technology, Rhodes island, Greece, 1-3 Sep. 2005 (A-829 to A-835)

18. López-Rodriguez, F. y. Pérez Atanet, C. 2006. Ahorro y eficiencia energética en el sector agroalimentario..

19. Mangitel Campos, J.L (2002). Guía de Aplicación de Buenas Prácticas de Manufactura: Extracción de Aceite de Oliva. . Argentina

20. MAPA, 2005. Descripción, condiciones y primas de las medidas agroambientales. http://www.mapya.es/es/desarrollo/pags/magam/pr_medidas.htm

21. MAPA. 2005. Ministry of Agriculture, Fishery and Food Rural Development webpage. http://www.mapya.es/en/desarrollo/desarrollo.htm
22. Martínez Alier, J. (1987). Ecological Economics. Blackwell: London
23. Milà i Canals, L.2003 “Contributions to LCA methodology for agricultural systems. Site-dependency and soil degradation impact assessment.” Directores: Xavier Domènech i Antúnez y Joan Rieradevall i Pons. Universitat Autònoma de Barcelona, Departament de Química. Available at en:< http://tdx.cbuc.es/TESIS_UAB/AVAILABLE/TDX-1222103-154811/>
24. Sánchez de Puerta, F (2004). “Sobre los costes sociales de la agricultura moderna: Un comentario a Frederick H. Buttel”. Ecología Política, 108.
25. Sánchez de Puerta, F. (2005). Medioambiente y Agricultura:¿La Nueva ‘Cuestión Agraria’ del Siglo XXI?. Una Primera Aproximación al Estudio de la Generación, Difusión, Adopción y Aplicación de las Medidas Agroambientales Europeas en Andalucía. Unpublished
26. Sánchez De Puerta, F. Y Taberner, J. (1995): "Innovación y alienación en la Agricultura: Una perspectiva socioecológica" en Agricultura y Sociedad, Nº 74, pp. 159-177.
27. Sánchez Romero, A. TRANSFORMACIÓN DE SUBPRODUCTOS DE ALMAZARA EN ABONO ORGÁNICO. BOLETÍN Nº 44/ 00. C.A.A.E.
28. Seoánez Calvo, M., Bellas Velasco, E., Ladaria Sureda, P., Seoánez Oliet, P. TRATADO DE RECICLADO Y RECUPERACIÓN DE PRODUCTOS DE LOS RESIDUOS (2002). Ed. Mundi-Prensa, Madrid.
29. Stobbelaar, D. J., Kuiper, J., van Mansvelt, J. D., Kabourakis, E. Landscape quality on organic farms in the Messara valley, Crete. Organic farms as components in the landscape. Agriculture, ecosystems and environment 77 (2000) 79-93
30. Tombesi A., Michelakis N., Pastor M., Recommendations of the working group on olive farming production techniques and productivity, Olivae 63, International Olive oil Council, Madrid, Spain, 1996
31. UNASUR (2005). Manual de Buenas Prácticas Agrarias en el Olivar. Jaén. 245 pp.
32. www.tdcolive.net
33. www.actahort.org

34. www.agriculturenews.faorne.net

35. www.fao.org

36. www.agroecology.org/cases/organicolive.htm