# IENICA

## REPORT FROM THE STATE OF GREECE
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## Executive summary

**1.** Since the early ’70s, the Greek agricultural sector has dramatically shrunk. Its contribution to total employment and GDP has significantly decreased: from 40.6% and 18.9% in 1972, to 21.6% and 13.9% in 1992, respectively.

**2.** The total agricultural land of Greece is about 9Mha, of which about 4Mha is arable land and 5Mha pastures. About 30% of the Greek arable land is irrigated, whereas approximately 50% are located in hilly areas.

**3.** The vast majority of Greek farmers are old and of limited educated: about 90% are older than 55 years of age, and only ca. 5% have graduated from secondary school. This is thouight to be a critical factor for any land reallocation in favour of new industrial crops.

**4.** The main cultivated crops in terms of land use are wheat, cotton and maize corn. These three crops together occupy more than 40% of the total Greek arable land. However, wheat (21.5% of the arable land) has very low grain yields compared to those achieved in Middle European countries.

**5.** Among the new industrial crops examined in the last ten years, Sweet sorghum and Eucalyptus have shown very high yields. These yields, as achieved in experimental plantations, are among the highest throughout the European Union.

**6.** Several Greek research groups have been focusing their R&D&D activities towards the development of better varieties of traditional industrial crops (suger beet, cotton, tobacco, cereals), as well as on achieving optimal yields with a few new industrial crops (sorghum, miscanthus, arundo, eucalyptus, cynara, kenaf, etc.). These efforts are funded by, both, the Greek government and the European Commission.

**7.** The cultivation of industrial crops in hilly agricultural areas could reduce endemic soil erosion and significantly limit other negative types of environmental impact generated from current agricultural practices.

**8.** A solid legislative framework concerning the production and use of industrial, particularly non-food crops is absent in Greece. The supply side is mostly regulated by the EU’s Common Agricultural Policy. On the demand side, a law entered into force in 1994 that offers the opportunity to local authorities, organisations, and private investors to exploit the renewable energy sources potential, including agricultural and forest biomass.

# Agriculture in Greece

The term “agriculture” refers to every human activity, which is based on the deliberate and controlled use of mainly terrestrial plants and animals and aims primarily at the satisfaction of humans food and non-food needs. Thus it includes production system (i.e., cultivation of crops), the food processing industry and, finally, the distribution and trade system which secures that all these products reach the consumers. This report focuses only to the agricultural production sub-system.

During the period 1972-1992, there has been a dramatic decrease of the contribution of agriculture in the economy of Greece. More precisely, the contribution of the agricultural sector

- in total employment terms, has decreased from 40.6% in 1972 to 21.6% in 1992.
- in GDP terms, has fallen from 18.9% in 1970 to 13.9% in 1992.

Moreover, during this period there was a gradual change in the trade balance of agricultural products, which resulted in the shift of Greece from net exporter to net importer o agricultural commodities.

*Land resources*

The total agricultural area of Greece is about 9Mha, of which about 4Mha is arable land and the remaining 5Mha is public and private pastures. About 50% of the arable land is located to hilly areas thus resulting in unfavourable farming conditions. The total irrigated land is about 1.2Mha and in the following years it is expected to reach 1.6Mha.

The total number of agricultural holdings is 820,000. The vast majority of these have a very small size. More precisely, 75% of them are less than 5ha, whereas the average size is 4.3ha. The small farm size and, subsequently, the low income are among the most important factors inhibiting the entrance of young farmers in the agricultural sector.

*Labour resources*

As already mentioned, during the period 1972-1992 there has been a dramatic decrease of the contribution of the agricultural sector in total employment. A quantitative and qualitative analysis of the people employed in agriculture has shown that

- the number of employees has been reduced from 61 to 23 persons per 100ha; however, this figure is still considered rathe high; and
- the Greek agricultural sector is dominated by old and low educated farmers. More precisely,
  - 57% of the farmers are older than 55 years of age, and 30% older than 65;
  - more than 94% of employees and farmers have had a very limited (elementary or lowere) education.

## Current production and use of agricultural crops for non-food uses

The total agricultural land use in Greece has during the last 25 years increased by 11%, being today (data for year 1995) almost 9.0Mha,[1] thus comprising 4.5% of the total EU agricultural land (174Mha) (FAO, 1995).

Among the plant species cultivated in Greece, several have been selected as the most promising for industrial purposes. These species can be divided in the following three categories (Table 1):

- *traditional crops (for food and non-food uses);*
- *new crops (exclusively for non-food uses); and*
- *agro-forestry crops (that can be cultivated on agricultural land, mainly for bioenergy and paper production).*

**Table 1.** Crops with high potential for industrial use.

| Traditional crops | | New crops | Agroforestry crops |
|---|---|---|---|
| *For food & non-food uses*[2] | *For non-food uses*[2] | *Non-food uses* | *Non-food uses* |
| Maize | Cotton | Sweet Sorghum | Eucalyptus |
| Wheat | Tobacco | Miscanthus | Poplar |
| Potato | | | |
| Sugar beet | | | |
| Sunflower | | | |

The above selection of crops has been based on data for current situation and foreseeable major changes (e.g., of set aside land schemes, level of subsidies, etc.) within the Greek and Western European agricultural sector. Furthermore, the selection of new industrial and agroforestry crops was based on the following additional criteria:

- Efficient conversion of sunlight into plant material;
- Efficient water use, as this is one of the primary factors limiting biomass production, especially in the Mediterranean;
- High dry matter content of the plant biomass at the time of harvest;
- High energy density (MJ/kg); and
- Lowest possible level of environmental impacts and other externalities.

[1] Mha: million hectares.
[2] Residues from these crops can also be utilised for non-food purposes (mainly for energy production).

## Traditional crops

The area cultivated with the traditional crops selected above, as well as their yields (years 1970-1995) are shown in Table 2. In the following parts, we provide more information on each industrial crop of this type.

**Table 2.** Area (1000ha) and yields (fresh t/ha) of traditional agricultural crops.

| | ***1970*** | | ***1975*** | | ***1980*** | | ***1985*** | | ***1990*** | | ***1995*** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Area* | *Yield* | *Area* | *Yield* | *Area* | *Yield* | *Area* | *Yield* | *Area* | *Yield* | *Area* | *Yield* |
| Maize | 169.5 | 3.1 | 127 | 3.8 | 172.5 | 7.4 | 221.7 | 8.6 | 207.6 | 9.7 | 173.1 | 10.6 |
| Potatoes | 58.6 | 12.9 | 57.3 | 15.3 | 65 | 16.6 | 56 | 18.2 | 50.3 | 18.9 | 50.6 | 20.7 |
| Seed cotton | 143 | 2.3 | 138.3 | 2.6 | 142.4 | 2.5 | 236 | 2.1 | 259 | 2.5 | 441.2 | 2.8 |
| Sorghum[3] | 8.9 | 0.8 | 5.0 | 1.4 | 1.5 | 1.7 | 1.0 | 2.1 | 1.0 | 2.0 | 1.0 | 2.0 |
| Sugar beet | 26.3 | 51.6 | 44.1 | 60.4 | 28.9 | 57.5 | 41.5 | 60.6 | 45.6 | 60.5 | 40.1 | 63.2 |
| Sunflower | 1.5 | 1.0 | 2.0 | 1.3 | 3.3 | 1.5 | 57.7 | 1.6 | 27.2 | 1.5 | 22.8 | 1.5 |
| Tobacco | 98.3 | 0.9 | 97 | 1.2 | 89.3 | 1.3 | 96.9 | 1.5 | 78.8 | 1.7 | 65.2 | 2.2 |
| Wheat | 974.8 | 1.9 | 925 | 2.3 | 1012 | 2.9 | 883 | 2.1 | 1003 | 1.9 | 860.8 | 2.7 |
| **Total** | ***1490*** | | ***1396*** | | ***1474*** | | ***1594*** | | ***1673*** | | ***2515*** | |

### *Wheat*

Wheat is an annual grass belonging to the family of cereals and can be seen as a representative for several grain crops (barley, rice etc). World-wide, it is the most important cereal crop, with a total grain production of 585Mt/year (FAO, 1996). In Greece, wheat is the most widely cultivated annual crop.

The comparatively high protein content of wheat grain makes it the most important source of human nutrition in the world. Moreover, several by-products of wheat-based food industries have created outlets for technical and industrial applications, namely wheat germ oil, wheat gluten and wheat starch, as a food component or for ethanol production after fermentation.

In Western Europe the cultivated area with wheat has been reduced during the period 1990-1995, but wheat grain production has remained rather constant, thus indicating a slight increase in land productivity. The same pattern stands for Greece as well, where a reduction of approximately 0.15 Mha has been noted.

Wheat yields in Greece and in other Southern European countries are much lower (2.7 t/ha in Greece) than the yields achieved in Middle Europe (FAO, 1995). In general yields depend upon climatic and soil conditions, as well as other factors, such as variety of cultivar, size of kernel, etc. According to Salunkhe (1992), the moisture content of grain is about 10%.

[3] data refer to fibre sorghum which is cultivated for feed purposes

Straw is the major by-product of wheat production, constituting one of the principal presently available biomass sources arising from present agricultural activities in Greece. Based on the wheat harvest index, which is about 0.6 (Bassam, 1998), the estimated yield of straw is 1.2 odt/ha (assuming a 10% moisture).

Wheat propagates by seeds and requires a minimum number of tillage operations to help prevent soil compaction and restriction of root and water penetration. Rates of seeding differ with the type of wheat, size of seed and locality. Generally, the use of 33 kg of seeds/ha is recommended (Duke, 1983). A critical factor for the wheat yield is fertilisation; according to Harris (1998), nitrogen requirements for wheat cultivation in Western Europe range between 100 and 180 kg N/ha.

According to Briggle (1980), the direct energy requirements for wheat cultivation are 3.23 GJ/ha for spring wheat, and 4.46 GJ/ha for winter wheat. These figures refer to the energy required for several operations like planting, fertiliser and pesticide application, irrigation, harvesting etc.

The current production and uses of wheat in Greece are shown in Appendix I.

***Maize***

Maize is a tall annual plant that belongs to the cereal grain crop category. Its height varies greatly, according to plant growth conditions and genetics. Maize follows the C4 metabolic pathway and is photosynthetically highly efficient under conditions of high temperature and light intensity. The nutritional value of maize is lower than most other cereals but, after wheat and rice, is the most important cereal in the world. Western European countries are the largest importers of maize, since this crop is not cultivated as widely as wheat.

The highest proportion of maize production is directly used for animal feed. Furthermore, significant amounts of corn are yearly used for human food, in vegetable, fresh, canned or frozen forms. Finally, maize corn can be converted into various industrial products, including starch, syrup, dextrin, corn oil, etc. These substances are used in the printing, confectionery, tanning leather, plastics, food, brewing, soap, paint, and textile industries.

In Greece, the total area cultivated with maize is about 0.17Mha with an average productivity of 10.6 t/ha. This yield is among the highest yields in European countries. The average yield of maize in Middle Europe is 8.02 tonnes fresh matter/ha (FAO, 1995). The total usable production of maize in Greece is 1.72 Mt/yr, most of which is directly used as animal feed (see Appendix I).

Maize propagates by seeds, and its cultivation requires similar operations to those for wheat cultivation. Seed rates of 11.5-16 kg/ha are considered normal (Duke, 1983). Commercial fertilisers are used to supply one or more of the most frequently deficient nutrients. Nitrogen fertilisers promote quick and vigorous growth of stalks and leaves. According to Harris (1998), nitrogen requirements range from 110 to 160 kg N/ha. The direct energy input and labour requirements for maize production are considered similar to those required for wheat cultivation.

The current production and uses of maize in Greece are shown in Appendix I.

***Sugar beet***

Cultivated forms of sugar beet are biennial plants, which are grown for their roots. The beet roots contain up to about 20% (on fresh weight basis) sugar, thus making according to Duke (1983) sugar beet the second most important source of sugar in the world, after sugar cane. This sugar content can be recovered by appropriate processing of the beet roots. During processing, one can also obtain several by-products like molasses, dried pulp and filter cake. Molasses are usually combined with beet pulp to provide animal food or used as fermentation feedstock in the chemical and pharmaceutical industries for bioproducts such as citric acid and its esters (IENICA, 1998).

Sugar beet is cultivated in all countries of the Middle and Southern region of Europe. In Greece, the area cultivated with sugar beet in 1995 was about 0.04Mha with a total production of 2.61Mt of fresh matter. The average yield is about 63 t fresh matter/ha (FAO). Due to the high moisture content of the roots (85%), the average dry yield of sugar beet is 9.5 odt/ha/yr.

The sugar beet requirements for N fertilisers range from 55 to 110 kg N/ha (Martin et. al., 1976). According to Graef et. al. (1994), the total energy input for sugar beet cultivation is about 33.7 GJ/ha.

The current production and uses of sugar beets in Greece are shown in Appendix I..

***Potato***

Potato is cultivated for its tubers, which are stem structures formed by the enlargement of the tips of underground stems. Along with cereals, potato tubers are the major sources of carbohydrate in the European diet. Secondary uses include the production of starch and dextrose, industrial alcohol by fermentation and spirits (Halley, 1983). Paper and board industries are the largest non-food, starch-using sector, consuming approximately 60% of the total industrial starch.

In 1995, the area dedicated to potato plantations in Greece was about 0.05 Mha, whereas the average yield was 20.7t/ha. During the period 1990-1995, the area cultivated with potatoes has remained stable, but the yield has been increased 9%. Based on its high moisture content, i.e., 80% (Rexen and Munck, 1984), the dry matter yield of potato is estimated at 4.2 odt/ha/yr, which is among the lowest yields in European countries.

The total production and uses of potato are shown in Appendix I.

***Sunflower***

Sunflower is cultivated primarily for its seeds, which yield one of the world's most important sources of edible oil. Sunflower oil is used for cooking, in margarine production, as salad dressings, for lubrication, soap production, etc. In addition, it is suitable for a range of other industrial uses.

The total production of sunflower seeds in Greece was 0.33 Mt, which are mainly processed for the production of sunflower oil (edible) and sunflower cake (for animal feed).

Sunflower is a well-adapted crop under various climatic and soil conditions, but it performs best on freely drained and deeply worked soils. Seed rates of 8-10 kg/ha (Smith et al., 1997) are considered normal. A critical factor for high yields is irrigation. Grown on the same field,

irrigated sunflower yields have been observed to increase up to 100% or more in comparison to non-irrigated plants (Bassam, 1998). However, water use efficiency depends on fertilisation. Nitrogen requirements range from 50 to 75 kg/ha (Smith et al., 1997).

Energy and labour inputs are considered similar to those for rape cultivation.

The currently cultivated hybrids in Greece achieve an average yield of 1.5t/ha, whereas the average productivity in Middle European countries is 2.5 t/ha of fresh matter (FAO).

The sunflower crop generates annually significant amount of plant residues, mainly stalks, which remain in the field. On the average, stalk residues are estimated as twice as much as the seed production (Bassam, 1998). Additionally, the non-seed part of the heads is also an important biomass source that is almost equal in dry weight to seed production. These residues have a high gross heating value of about 17 - 18 MJ/kg.

According to Smith et al. (1997), the total area of sunflower growth in Europe has been expanding steadily and seems likely to continue to do so; within that total, the industrial crop area is also expected to rise.

**New crops**

Although the two new crops selected (Sweet sorghum and Miscanthus) are not presently cultivated in Europe, they have recently received much R&D attention in the EU, since they can generate raw materials for a number of energy and industrial outlets.

***Sweet sorghum***

The sweet or fibre sorghum biomass can be used for energy purposes, i.e., as a feedstock of biofuels that can substitute fossil fuels. In addition, the sorghum stem fibre has interesting paper-making and other useful industrial characteristics.

The main industrial use of sweet sorghum considered in European studies is in ethanol production. This industrial process starts with the extraction of the sugar-rich juice from the sweet sorghum stalks; then, the juice is concentrated and fermented, in order to produce high-alcohol solutions, which can be finally distilled to produce anhydrous ethanol. The alcohol produced can be either directly used as fuel - neat or in mixtures with gasoline - or transformed into gasoline additives (ETBE).

In experimental plantations, sweet and fibre sorghum crops have shown very high yields. According to several authors (Curt, et. al., 1996; Dalianis, et al., 1996; Losavio et. al., 1994), the yields of sweet sorghum range from 115 to 141 t fresh matter/ha, whereas the total dry plant matter productivity ranges between 22 and 45 dryt/ha (average 35.5 odt/ha). The main factors determining yields are irrigation, N fertilisation, and plant density. These yields refer to the total, harvestable, above-ground biomass.

Sweet sorghum stem accounts for 85% of the total, above-ground biomass, with a sugar content ranging between 30 and 45% on dry-biomass basis (Dalianis, 1997), equivalent to 12-13.8 t/ha sugar; the same plant, under appropriate cultivation management, can yield up to 6,750 L/ha of ethanol.

Based on all available studies, the cultivation of both types of sorghum in Greece is especially promising.

### *Miscanthus*

Miscanthus is a tropical and subtropical grass, which at present is only cultivated for experimental purposes in Europe. At experimental plantations in Southern European countries, the mean yield achieved was 23.6 dry t/ha (McCarthy & Mooney, 1994).

Harvested miscanthus biomass can be used for thermal and electrical energy production via several conversion routes (combustion, gasification, etc.), as well as for paper-pulp production. The paper produced from miscanthus using the kraft pulping process has properties similar to that from Eucalyptus pulp (Bao et. al.1992).

## Agro-forestry crops

### *Poplar*

Different *Populus* species (family Salicaceae) grow in temperate climate zones. Poplar is presently considered as a short rotation coppice crop (SRC), cultivated as a biomass plantation, for use by direct combustion, production of (briquetted or not) solid biofuel, and in gasification.

According to Kuiper & Kolster (1996), and Bonduelle et. al. (1996), the yield of short rotation poplar ranges between 9 and 15 odt/ha, whereas an average yield of 12 odt/ha is considered as achievable under typical farming techniques. As far as the long rotation poplar plantations are concerned, yields range between 6 and 10 odt/ha. According to Kuiper & Kolster (1996), new clones of poplar can reach a maximum yield of 25 odt/ha.yr.

### *Eucalyptus*

Eucalyptus species are native to Australia. During the last two centuries, eucalyptus species have spread from Australia into many tropical and subtropical regions of the world. Although several eucalyptus types have been adopted in certain Mediterranean countries, the two most important species in that region are *E. camaldulensis* and *E. globulus*.

These two species are highly adaptive and grow rapidly in a wide range of climatic conditions. Sensitivity to low temperatures is the most important environmental factor limiting the latitudinal and altitudinal range over which it can be planted. (Bassam, 1998) According to Pereira et. al. (1996), European eucalyptus plantations could provide wood as an important raw material for the pulp industry, especially in Portugal and Spain, where approximately 1 Mha have been planted.

Growth of eucalyptus responds strongly to climatic conditions and production yields may vary within a wide range of values. According to Dalianis et al. (1996) and Pereira et. al.(1996), the biomass yields of Eucalyptus at experimental plantations in Southern European countries range between 10 and 25 dry t/ha after the 1$^{st}$ rotation, whereas the yield increases after the 2$^{nd}$ or 3$^{rd}$ rotation, achieving a maximum yield of 35.2 dry t/ha.yr. An average yield of 16 dry t/ha.yr is considered reasonable.

# Opportunities and constraints for the development of agricultural biomass for non-food purposes in Greece

## Science and Technology

As already mentioned the low level of education among the Greek farmers is an obstacle for the introduction of non-food crops in the agricultural sector of Greece. At present where there are not well-established markets for these crops it is very difficult to persuade farmers to shift towards the cultivation of industrial crops.

The previous analysis has shown that the achieved yields of most of the traditional crops are quite low in comparison to the yields achieved in Middle European countries. Thus, most of the research institutes and universities involved with the cultivation of these crops focus their activities towards developing better varieties.

On the other hand the new and agro-forestry crops have shown very high yields. Although the previous mentioned yields are from experimental plantations where irrigation, N fertilisation and plant density are optimised, it is believed that these crops show a very good adaptation to Greek soil and climate. Thus it is considered necessary to continue the research in this field in order to optimise cultivation techniques, and to improve processing operations.

Moreover there several research groups participating in projects funded either by EC or national government aiming to

- optimise the conversion processes to end products
- develop economically viable processes for new products

## Environment

The highly mechanised and intensive farming during the previous years has generated numerous environmental burdens. More precisely in Greece the following environmental problems are of crucial importance

- pollution of groundwater bodies due to excessive use of fertilisers
- soil erosion and desertification of mainly hilly areas at several islands where the agricultural land has been abandoned because it is not considered profitable and
- loss of biodiversity attributed mainly to the adaptation of monocultures and the excessive use of pesticides.

The measures taken to protect the environment are not considered efficient enough to reverse the current situation.

On the other hand the cultivation of non-food crops offer a good opportunity for the protection of environment. The use of land for the production of industrial crops will slow down the soil erosion and the impact of fertilisers leaching. However more research is required to assess the environmental impacts from their large-scale cultivation.

Moreover the end products are considered environmentally friendly i.e. they do not contribute to global warming, they are biodegradable etc.

**Legislative**

Like in most European countries the absence of a solid legislative framework concerning the production and use of non-food crops is obvious. It is considered necessary to establish such a framework in order to guarantee economic and agricultural profitability, stability and security of supply.

In Greece the legislative framework concerning the supply side is strictly related with the Common Agricultural Policy.

As far as the demand side is concerned, a law (2244/94) which entered into force in 1994 gives the opportunity to local authorities, organisations and private investors to exploit the renewable energy sources potential.

**Economic**

Undoubtedly the main factor determining the large scale exploitation of non-food crops is their economics. Currently both production of non-food crops and their conversion to end products are not economically viable.

Considerable research efferts are required to optimise farming practices in order to lower the cost of feedstocks and consequentlty making them competitive with fossil feedstocks.

Moreover it is required to optimise industrial processes and encourage conversion of byproducts to saleable commodities.

Finally the internalisation of the external costs will improve the copmpetitiveness of such products.

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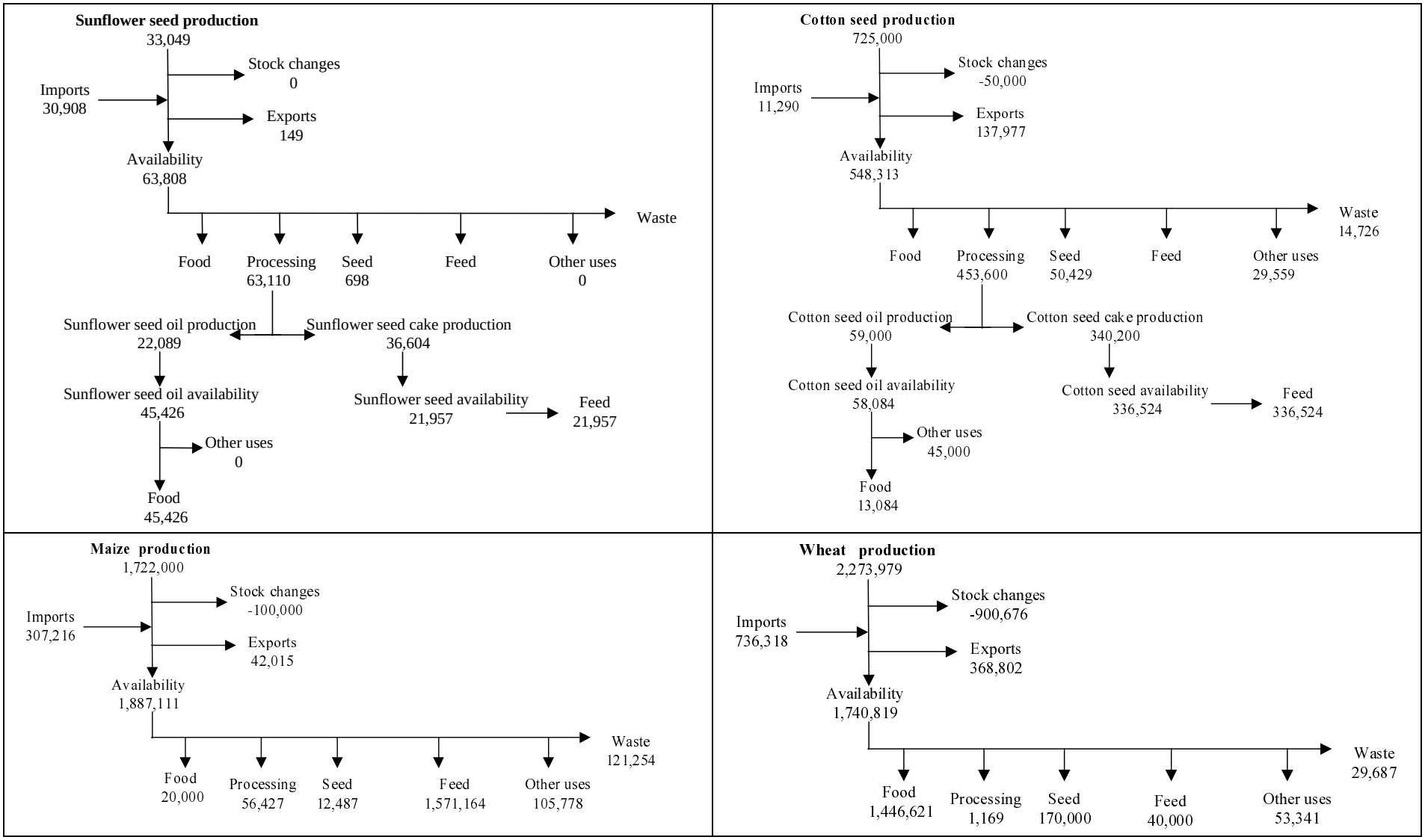
**Appendix I -Main use of agricultural feedstocks in Greece (in metric tonnes of fresh matter) *(Source: FAO Agricultural databases, 1995).***



**Main use of agricultural feedstocks in Greece (in metric tonnes of fresh matter)** ***(Source: FAO Agricultural databases, 1995)***

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