Ecological and economic sustainability of rice cultivation in Europe and the Mediterranean region

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Abstract

Rice is at present an important crop in many European and Mediterranean areas, where it is cultivated on a total of about 1,300,000 ha. The most important rice-producing countries are Egypt, Italy and Russian Federation. The average crop yield is quite variable as it ranges from 9.8 t ha^{-1} in Egypt to 3.4 t ha^{-1} in Russian Federation. Rice is cultivated in different types of soils: light, heavy, hydromorphic. In some regions, soils are saline or very saline. Most rice fields are permanently flooded with waters mainly coming from rivers. About 80% of the European and Mediterranean rice area is cultivated with *japonica* varieties and the remainder with *indica*-type varieties. In the European rice area the spread of mechanization led to the increase of the average farm size. Average milled rice consumption ranges from about 5 kg $capita^{-1}$ yr^{-1} in most European countries to 42 kg $capita^{-1}$ yr^{-1} in Egypt. In Southern European countries about 80% of the consumed rice belongs to *japonica* varieties, while in Northern Europe long-grain *indica*-type varieties are usually preferred. Main qualitative traits of rice are related to the shape, colour, processing and cooking features of the grains. Rice eco-systems are currently facing with numerous issues, such as poor crop establishment, low temperatures, water scarcity, biotic and environmental stresses, inefficient agronomical practices, which result in a low return from rice production. Most of these issues can be addressed by improving the co-operation among rice research institutions and applying rice integrated crop management systems.

Keywords: Rice ecology; Rice farm organization; Rice market; Rice constraints, Rice quality

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Paper presented at First Asia-Europe Workshop on Sustainable Resource Management and Policy Options for Rice Ecosystems (SUMAPOL 2005), 11-14 May 2005, Hangzhou, Zhejiang Province, P.R. China

1. Rice area and yield

Rice production in the Mediterranean regions dates back to 7th century. Rice was first introduced into Egypt and gradually spread towards the 15th century to most countries of the Mediterranean basin.

Rice is at present an important crop in many European and Mediterranean areas, where it is cultivated on a total of about 1,300,000 ha. The most important rice-producing countries are Egypt (660,000 ha), Italy (226,000 ha) and Russian Federation (175,000 ha) (Table 1). In most countries rice production mostly occurs in concentrated areas such as the lower valley of the Nile river in Egypt, the Po valley in Italy, the Kuban valley in Russian Federation, the Rhone delta in France, the Thessalonica area in Greece. In Spain and Portugal rice cultivation is scattered in several areas such as Aragon area, Ebro delta, Valencia Albufera, Guadalquivir valley in Spain, Tejo and Mondego valley in Portugal. The average crop yield is quite variable, as it ranges from 9.8 t ha^{-1} in Egypt to 3.4 t ha^{-1} in Russian Federation. In Egypt the average yield has increased dramatically in the past 20 years, from 5.7 t ha^{-1}, in 1985 to 8.2 t ha^{-1} in 1995 and 9.8 t ha^{-1}, in 2004.

Table 1. Evolution of rice area (ha) and yield (t ha^{-1}) in Europe and Mediterranean countries in 1994–2004 (FAOSTAT, 2005).

Country	Area (ha) [1] 1994	Area (ha) [1] 2004	Yield (t ha^{-1}) [2] 1994	Yield (t ha^{-1}) [2] 2004
European countries				
Italy	223,000	226,000	6.15	6.62
Spain	105,000	115,000	6.80	7.35
France	18,000	20,500	5.70	4.90
Greece	22,500	23,500	7.52	8.45
Portugal	24,000	27,000	6.04	6.23
Russian Federation	185,000	144,000	3.04	3.35
Ukraine	21,500	18,000	4.14	4.45
Total[1] – Weighted mean[2]	599,000	574,000	5.47	5.90
Mediterranean countries				
Egypt	580,000	630,000	7.98	9.78
Turkey	59,000	79,500	4.94	5.25
Total[1] – Weighted mean[2]	639,000	709,500	7.69	9.27

Within Western Europe, highest rice yield occurs in Greece and Spain. In the period 1994-2004 rice yield in these countries increased steadily from 7.52 t ha^{-1} and 6.80 t ha^{-1} in 1994 to about 8.45 t ha^{-1} and 7.35 t ha^{-1} in 2004, in Greece and Spain, respectively. In the last decade France average yield showed a significant reduction because of the unfavourable climatic conditions recorded in 2004. Over the same period average rice yield slightly increased also in Eastern Europe with a variation from 3.04 to 3.35 t ha^{-1} and from 4.14 to 4.45 t ha^{-1} in Russian Federation and Ukraine, respectively.

2. Ecological and agronomical scenario

Rice is cultivated in a wide range of ecological conditions. According to FAO classification, in most European areas the primary climate of rice production is temperate-continental, with a cold winter and warm summer and main rainfall occurring during the first stages of the crop growth (April-June) and the harvesting period (September-October) (FAO, 1996). In the Mediterranean countries the climate is sub-tropical (Mediterranean climate) with a dry summer, with warm, dry, clear days and long growing season. Rice is mostly grown in different types of soils: light, heavy, hydromorphic and saline; most are fine textured poorly drained with impervious hardpans or clay pans of these soils are well suited to rice production, like those with low water permeability that are not much suitable to other crops. In the Valencia area (Spain) rice is cultivated in marshlands of a coastal lagoon. The pH is from 4 to 8 and organic matter from 0.5 to 10%. In some regions (e.g. the Camargue in France, Ebro delta in Spain, Nile delta in Egypt, Kuban valley in Russian Federation) soils are saline or very saline.

Basins (rice fields) are permanently flooded with some drainings during cultivation for crop rooting, fertilization and herbicide spraying. In the conventional irrigation system water is usually supplied and regulated through a series of floodgates from the topmost to the bottommost basin. In some regions of Spain and Russia Federation water may be supplied to each basin through a head ditch. Water depth into the basin is kept at 5–7 cm during the first stages of the crop growth, in order to promote rice growth and root anchorage and at 10-15 cm after rice tillering, mainly to avoid pollen sterility effects caused by low temperatures during crop flowering. On average 18,000 to 40,000 m^3 ha^{-1} are required over a cultural season.

Most of the irrigation water comes from rivers (Nile in Egypt, Po in Italy, Kuban in Russia, Ebro in Spain, etc.) and lakes (Albufera in Spain).

Seedbeds are commonly prepared by ploughing in autumn, right after the harvest of the previous rice crop in springtime in the following year at a depth of about 20 cm.

Minimum tillage practices are sometimes applied mainly to adopt stale seed bed practice in order to favour weed germination and to control them before rice planting.

Precision land grading, obtained with laser-directed equipment, is an agronomic practice that has greatly contributed to improve water management and consequently obtain a higher crop stand establishment and more effective weed control. Precision levelling also improves water use efficiency. Following the adoption of laser levelling technology in the late 1980s more than 80% of the western European rice land was precision-levelled.

Rice is planted from early April to end-May and harvested from mid-September to end October. In Western Europe, rice seeds are soaked in water for 24 hours before planting and then mechanically broadcasted in flooded fields. Unsoaked seeds may float on the water surface and distribute unevenly in the field. In most countries planting operation is carried out by ground equipments; in Spain and Russian Federation is sometimes done by airplane. In about 40,000 ha, mostly in Italy rice is drilled to dry soil in rows and managed as a dry crop until it reaches the 3–4 leaf stage. After this period, rice is permanently flooded as in the conventional system. In Russia Federation rice is frequently drilled to dry soil and flooded few days later. In Egypt transplanting is the most popular method of crop establishment.

Fertilization is mostly carried out by supplying mineral fertilizers (100, 50, 100 kg ha^{-1} of N, P, K, respectively). Surveys carried out in north-west Italy pointed out that soil reaction of paddy soils is poorly related to the agronomic practices. As consequence of the massive use of fertilizers, in several sites the phosphorous content is very high, and could represent and environmental issue for surface water.

About 80% of the European and Mediterranean rice area is cultivated with *japonica* varieties and the remainder with *indica*-type varieties.

3. Farm organization

The mechanization of roughly all operations of rice cultivation and the spread of monoculture led to the increase of the average farm dimensions. This trend is still continuing, driven by the reduction of the crop profitability, the increase of the working capacity per ha and the cost of the machinery.

From 1983 to 2003, the number of farms dramatically diminished in all Western Europe rice producing countries. For example the total number of farm diminished to one-half in Italy and to one-fifth in Valencia area of rice cultivation (Table 2; Finassi and Ferrero, 2004). In the same period the mean area per farm showed an increase roughly proportional to the reduction of the number of farms (from 20 to 46 ha in Italy and from 1.9 to 4.7 ha in Valencia area). In Italy, the area managed by a single worker

Table 2. Rice area and percentage on total surface of farms grouped in classes in relation to the rice cultivated area per farm, during 1983-2003 in Italy (Finassi and Ferrero, 2004).

Year	< 10 ha (%)	11-25 ha (%)	26-100 ha (%)	> 100 ha (%)	Mean farm surface (ha)	Total area (ha)
1983	9.2	17.4	50.9	22.4	20.9	184278
1995	3.8	10.7	52.3	33.2	37.0	239256
2003	2.5	8.0	53.9	35.5	45.6	219986

can range from 40 to 60 ha and the farm size is then usually a multiple of that value. In Western Europe, the level of mechanization and cultivation technology applied in a small farm is not much different from that applied in a big farm, because of the high cost of labour and shortage of manpower. On average there is a tractor every 12 ha and a harvester combine every 60 ha. Most of the tractors bought during the last three years have more than 100 kW power.

In Western Europe many farmers, aged from 25 to 45 are graduated. The good returns obtained from rice cultivation during the period from 1970 to 2000 encouraged the young farmers to continue their parent activity. Education level in rural area of rice cultivation is significantly lower in Egypt and Turkey.

4. Rice consumption and market

The destination of rice produced in Europe and the Mediterranean regions includes human consumption (85%), animal feed (7%), industry (3%), seeds (3%) and loss (5%).

In the last 23 years rice consumption has significantly increased in all European countries either rice producers (Southern Europe) or non rice producers (Northern Europe). It is presumable that this trend will continue in the next years particularly in northern European countries (CEC, 2002). In the same period of time the increase in rice consumption has been remarkably high also in the other two main rice producers of the Mediterranean area, Egypt and Turkey. In all European countries average milled rice consumption ranges from 4.3 to 7.6 kg capita^{-1} yr^{-1}, except in Portugal were individual consumption is 16.3 kg capita^{-1} yr^{-1}) (Table 3). In Egypt, rice consumption of 2003 (41.6 kg/capita/year) roughly doubled the value recorded in 1980. Rice consumption showed in the last two decades a remarkable increase in European importing countries too, where once rice used to be considered as a curious food or a luxury product. At present there are no significant differences in consumption patterns

Table 3. Consumption of milled rice in European countries and main rice producing Mediterranean countries (kg capita^{-1} yr^{-1}) (FAOSTAT, 2005).

Country	1980 (kg capita^{-1} yr^{-1})	1990 (kg capita^{-1} yr^{-1})	2003 (kg capita^{-1} yr^{-1})
EU rice producing countries			
France	3.7	4.1	5.7
Italy	4.6	5.7	6.1
Greece	5.2	6.1	7.5
Portugal	15.1	15.7	16.3
Spain	5.3	6.2	7.6
EU non rice producing countries			
Germany	3.2	3.4	5.9
UK	3.3	3.7	4.3
Denmark	2.1	1.8	5.1
Non EU countries			
Egypt	22.5	32.4	41.6
Russian Federation	-	-	5.5
Turkey	1.8	4.3	7.2

between rice producing regions and rice importing regions of Europe. In importing countries rice is now of interest for diversifying conventional diets and its consumption corresponds to a lower potato and cooked vegetable consumption.

In Southern European countries about 80% of the consumed rice belongs to *japonica* varieties (mainly medium and long A type) and 20% to *indica* varieties, while in northern Europe long-grain varieties (long B type) are commonly preferred. In the United Kingdom and Denmark, for example rice consumption includes 85% of *indica* types and the balance of *japonica* types.

Very often local and ‘specialty’ varieties are claimed in these areas as guarantee of a production system respectful of the environment and are gaining a significant importance for small and medium farms in local markets. For example, in Italy varieties such as ‘Carnaroli’ and ‘Vialone nano’ have a good appreciation on local markets, also thanks to the promotion of their quality, through the attribution of APO (Appellation of Protected Origin) and the direct selling of rice by rice growers, who directly process their own rice production in the farm with small rice milling plants.

Demand in northern Europe (UK, and Scandinavian countries) is almost entirely for *indica*-type varieties, which are mainly imported from the USA, Thailand, India and Pakistan.

Two main issues characterize the European rice market scenario of the recent years: market liberalization and changes in consumer’s preferences.
Since 1995, imports from third countries increased by about 30%, as a consequence of the Uruguay Round agreements.

Market liberalization for rice will be applied starting from 2009. Tariff reductions will be phased in with a 20% cut in 2006, 50% in 2007 and 80% in 2008. In the meantime a duty-free quota, based on previous exports to the EU, has been established, with an increase by 15% each year until 2009, when all tariffs and quotas will be removed.

On 2003, EU Agriculture Ministers agreed on fundamental reforms to Common Agricultural Policy (CAP). Most relevant reform is the break in the link between subsidies and production. The primary aspects of CAP reform concerning rice are aimed at reducing the intervention price by 50%, and limiting the amount to 75,000 tons per year. These reductions are compensated by a subsidy devoted in part to environmental protection.

5. Rice production constraints

The most important constraints that affect rice productivity in Europe and Mediterranean regions include poor crop establishment, water scarceness, biotic and environmental stresses, low nutrient efficiency, low yielding capacity and high production costs.

Most water-seeded rice usually shows a poor crop establishment. The causes that can affect crop establishment are mainly related to the anaerobic conditions that occur during germination. The constraints of the poor crop establishment could be overcome by planting rice in dry soil, whenever possible, and developing new varieties with early vigour and good tolerance to low temperatures during germination.

As rice plants originate from sub-tropical and tropical zones, they are easily damaged by low temperatures at any growth stage from germination to ripening (Kaneda and Beachell, 1974). For example, if the heading of rice plants is delayed because of cold temperatures at the seedling stage, their pollen cells risk dying at the meiosis stage. Furthermore rice will also be subjected to a cool autumn and this will result in poor ripening. Even high temperatures may result in spikelet sterility, which can vary according to the plant growth stage.

Main water problems are related to a looming water shortage, uneven distribution, nitrate and pesticide pollution, waterlogging in heavy soils and the increasing costs of irrigation systems. The water problems can be tackled by developing more efficient water management strategies and providing new rice varieties that are more suitable for various water management conditions. The availability of varieties with a high early vigour allows the seeding of early rice directly in the soil and the use of rainwater in rainfed systems in much more efficient way. In these conditions rice can withstand weed competition and sudden submergence by early rains. New varieties that are suitable for a reduced use of water are also required in irrigated systems. The availability of short-cycle and high-yielding rice varieties is one of the ways for significantly curbing the irrigation water in a continuously flooded cultivation. A more consistent reduction of water consumption could be obtained by introducing profitable varieties that are suitable for discontinuous irrigation in all rice cultivation areas. These water management conditions could also contribute to the mitigation of methane emission due to rice field submergence. The new varieties should however also show a great capacity to suppress weed growth and tolerate soil salinity, as the cultivation in non-flooded conditions usually results in an increased competition of the weeds and a rise of soil salinity due to upward salt migration.

Rice is affected by the attack of weeds, diseases and insects. The failure to control these biotic stresses may potentially result in the complete loss of the yield (Oerke et al., 1994). Noxious organisms are usually controlled with pesticides. In Egypt and Turkey weeds are controlled with a combination of manual weeding and herbicides. The use of pesticides, mainly herbicides, may result in the appearance of resistant species (Busi et al., 2004), cause environmental pollution (Ferrero et al., 2001) and risk disrupting the precarious balance of the natural enemies to pests. The most successful ways of tackling main issues in rice weed management currently rely on the application of integrated crop management practices based on combination of herbicides with appropriate agronomic practices, such as tillage, soil levelling, water management, fertilization, variety choice. Several research projects are also addressing these issues by developing rice cultivars that are resistant to pests and diseases, highly competitive against weeds, with allelopathic traits and tolerant to safe and wide spectrum herbicides (Ferrero and Tabacchi, 2002). The use of these varieties combined with prophylactic measures will be a sound strategy to prevent damage or their spreading to rice.

Lodging resistance has been a key target trait to rise yield potential and is associated with many component traits such as plant height, stem strength, thickness, etc. Lodging-resistant rice cultivars usually show slow grain filling when nitrogen is applied in large amounts.

Reduced or variable milling yield, grain fissuring, grain shedding and non-contemporaneous maturity are other important issues that can affect rice productivity. Most of these problems are also related to other agronomic constraints, such as cold temperature and lodging, but are sometimes closely linked to the genetic features of the rice varieties.

The return from rice production showed a sharp reduction in the last 10 years in western European countries (Italy, Spain) as well as in the areas with less advanced agricultural economy (Egypt, Russian Federation). Since 1995 international rice prices started a marked declining process, while fertilizers, seed, crop protection products, custom application, fuel and labour started to have a significant increase. The cost of rice production in Italy or Spain is currently higher than that in the USA (200 € per ton of paddy rice against 100–130 €).

6. Rice quality

The quality of rice depends on many subjective and objective factors. Subjective factors are mainly related to the taste of the consumer and the intended end use of the grain. The demand of varieties with specific qualitative traits has notably increased in the more economically developed countries of Europe. Aroma is an important qualitative trait in specific varieties (Basmati-type). Demand for scented rice varieties has shown a significant increase since the early 1990s, primarily in UK and other European countries, because of a growing presence of Asiatic communities (Faure and Mazaud, 1996). It seems reasonable to expect a further increase in aromatic rice consumption in the years to come, throughout Europe, because of the increase in people migrating from far-east countries and the growing interest in ethnic cuisine. European consumption of Basmati rice is met entirely by imports from India and Pakistan. For this reason, specific research programmes need to be set up in order to develop scented varieties suited to European climatic conditions.

Main objective components of rice quality have been defined by the 'Regulation on the common organization of the market in rice' which has recently come into force in EU (Council regulation No 1785/2003). These are mainly related to the shape, colour and integrity of the grain. Other important components are milling quality, cooking and processing behaviour, grain fissuring. Grain shape is one of the major aspects of rice quality as it is usually associated with specific cooking characteristics. In most varieties, cooked long grain rice is usually fluffy and firm, while medium and short grain rice is soft, moist and sticky in texture. The demand among consumers in Europe is higher for long grain rice. The physical dimensions and weight are considered among the first criteria of rice quality that breeders consider when developing new varieties. According to the above mentioned European regulation, grain type categories are based upon three physical parameters: length, width and length and width ratio (Table 4).

The demand for long grain varieties increased significantly in the most recent years

Table 4. Grain type categories and other quality components of paddy rice.

Grain shape				Other quality components of paddy rice	
Type		Length (mm)	Length/Width ratio	Chalky grains[1]	1.5%
				Grains striated with red[1]	1.0%
Long	Long A	>6.0	>2.0 <3.0	Spotted grains[1]	0.5%
	Long B	>6.0	≥3.0	Stained grains[1]	0.25%
Medium		>5.2	<3.0	Amber grains[1]	0.05%
Short		<5.2	<2.0	Yellow grains[1]	0.02%

[1] percentage on wholly milled rice.

as a result of food diversification and immigration. The European Communities further encouraged this demand through the allocation of subsidies to rice growers who planted *indica* type rice. Subsidies were originally given to compensate for lower paddy and milling yields. The variety was often recorded in comparison to *japonica* varieties. To meet this demand many long grain varieties have been introduced in European countries. All these varieties are suited to temperate climatic conditions even if they are sometimes damaged by the low night temperatures, which occur particularly during the flowering period (Ferrero and Tabacchi, 2002).

According to the European regulation paddy rice of standard quality shall be sound and fair marketable, free of odour, with a wholly milled rice of 63% in whole grains (with a tolerance of 3% of clipped grains) and a maximum moisture content of 13%. Paddy should not show abnormal colour (green, chalky, striated, spotted, stained, yellow, and amber).

Grain fissuring may result in important negative effects during technological processes. Grain fissuring is often due to overexposure of mature paddy to fluctuating temperature and moisture conditions. Cracks in the kernel are the most common cause of rice breakage during milling. Milling degree is influenced by grain hardness, size and shape, depth of surface ridges, bran thickness and mill efficiency. Whole grain milling yield is the percentage of intact kernels to broken kernels after milling and separation. Producers are paid less for broken kernels than for whole.

Other specific quality traits are usually required for the production of processed rice such as parboiled, quick cooking or pre-cooked rice and rice flour. Rice parboiled for consumption as table rice, is generally a long grain variety. Medium grain rice is also parboiled, but it is more commonly ground into flour for use as an ingredient in food products (baked crackers, fried snacks).

7. Options for sustainable rice cultivation

Most existing high-yielding have a potential yield that usually exceeds actual yield that is obtained by farmers. The gap reflects numerous deficiencies in crop management. It has been demonstrated that much of this gap could be reduced by applying rice integrated crop management (RICM) systems (Clampett et al., 2001). The development and dissemination of RICM systems in Europe and Mediterranean countries could help to lower production costs and minimize environmental impact of agricultural practices (Nguyen, 2002).

The adoption of hybrid rice technology would be another major step in raising the yield potential (Christou, 1994). Hybrid rice varieties are ready to be developed in Egypt, where they have demonstrated to provide an yielding advance of 15–20% over the existing high-yielding varieties. The wide adoption of these varieties, however, still need technologies to increase the F1 yield and lower, consequently, the cost of the hybrid seed.

Research and subsequent dissemination of the resulting data is one of the most effective means for a sustainable improvement of the productivity and efficiency of rice-based systems. Numerous research programmes at a national or international level have been set up throughout Europe. They include main aspect of rice science from agronomic management to breeding, quality, environment and market aspects. Several research projects carried out in Europe and the Mediterranean regions have been fostered by Medrice, the FAO inter-Regional Cooperative Research Network on rice in the Mediterranean Climate areas. This organization was created in 1990 to promote scientific exchanges among rice scientists working in the Mediterranean areas and in other regions with a Mediterranean climate. Research Institutions from sixteen countries participate at present in Medrice: Bulgaria, Egypt, France, Greece, Hungary, Iran, Italy, Morocco, Portugal, Romania, Russian Federation, Spain, Turkey, UK, Ukraine, and Uzbekistan. Some of the important subjects considered in the collaborative research include resistance to blast, stem borers and diseases, quality and competitiveness of European rice, control of red rice, cataloguing of rice genetic resources in the region.

8. Conclusions

Rice is an important food crop in Europe and the Mediterranean areas. Mainly in less industrialized countries rice is still one of the main components of the human diet.

Rice eco-systems are currently facing with numerous issues, such as poor crop establishment, water scarcity, biotic and environmental stresses, inefficient agronomical practices, which result in a low return from rice production.

However, the significant progress made by rice science could offer a number of opportunities for sustainable development of the rice-based production systems in these cultivation regions. In the area of rice varietal improvement recent advances in hybrid rice is just an example of the successful contributions of science to the development of this crop. Research will also allow in the near future to introduce high yielding varieties tolerant to abiotic and biotic stress and to reduce the negative effects of rice cultivation on the environment.

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