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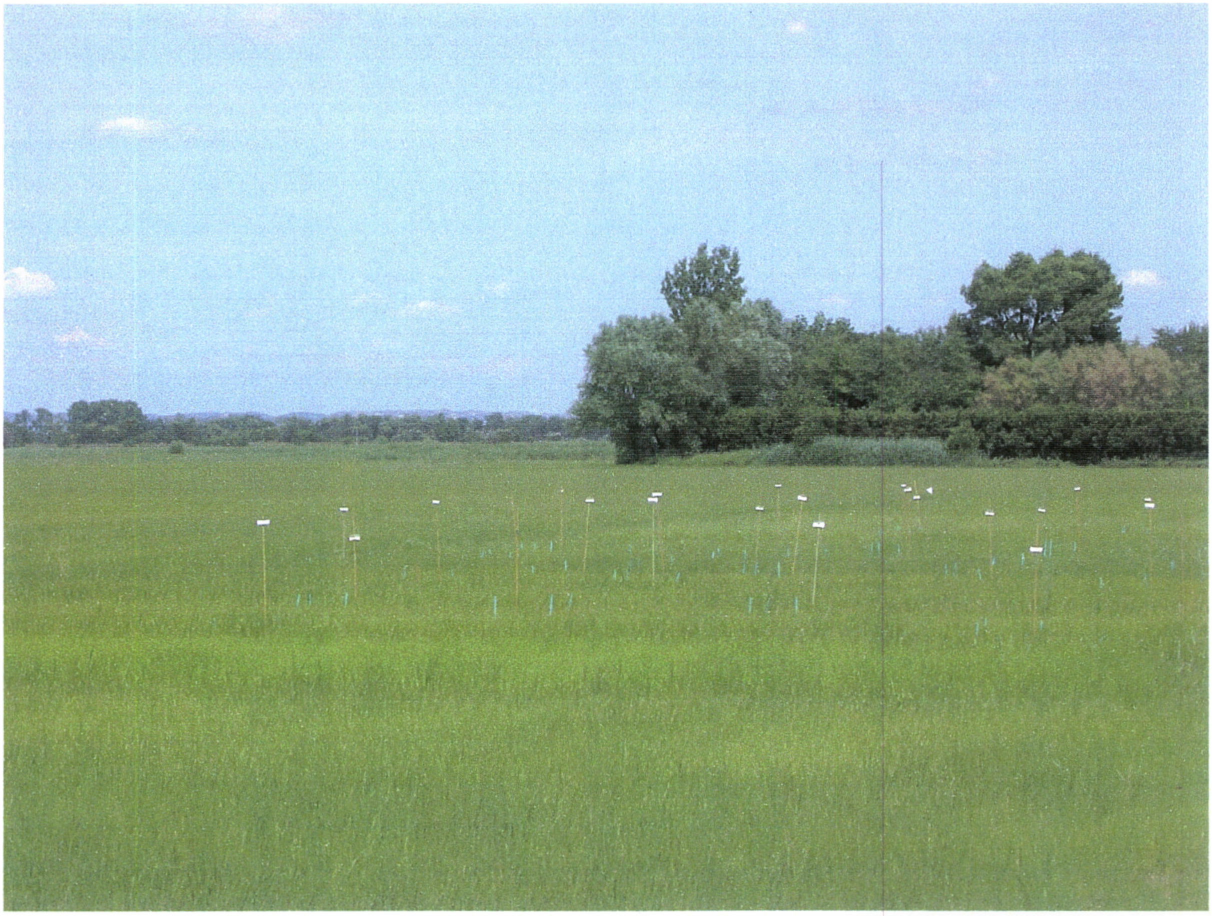
Characterization of rice crop systems and rice sector organisation in Camargue - France



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Summary

Introduction

Rice is grown in metropolitan France is in the Rhône delta—in the Bouches-du-Rhône department to the eastern part of the delta and in the Gard department to the west. The delta is where the river Rhône flows into the Mediterranean.
The delta area (the Camargue) has a total area of broadly 145,000 ha. It is bounded by the Crau plain in the east and the Costière du Gard hills to the west. Four units make a homogeneous ensemble: Plan du Bourg in the east, the Gard part of the Camargue and the Petite Camargue Saintoise in the west and 'Île de Camargue' or 'Grande Camargue' bounded by the two channels of the Rhône.

The area under rice totalled up to 32,000 ha in the 1960s. This has since stabilised at about 20,000 ha thanks to the 1980 plan for re-launching rice-growing, supported at the time by local authorities, the French government and the European Union.

The reform of the production support system and of the rice market undertaken recently by the European Union makes the future of the crop in the Camargue difficult. Indeed, gross earnings from rice production will decrease strongly following the fall in market prices.

There are two kinds of response to this conjunctural situation:

- either agriculture in the Camargue undergoes in-depth farming system reconversion, although strong environmental constraints (salt, soil, climate, etc.) in the Rhône Delta mean that the choice of management systems is limited,
- or it concentrates on production and products with a strong image as part of a territory project in which rice-growing contributes to the environmental balance.

With regard to the second aspect, the Camargue is already a recognised value at the national and international level. A key site for water birds, the Rhône delta is a major staging point for migrating birds on the way to Africa or Europe, according to the season.

The conservation of the delta wetlands depends on water and management, where quantity and quality are determinant factors in the ecological value of the delta. For this, irrigated farming has an important role to play in the Camargue.

Taking in nearly 400 million cubic metres of fresh water from the Rhône, rice growing leaves nearly 100 million cubic metres for the natural areas of the delta. Agricultural management of water should therefore contribute to the use of the Rhône delta wetlands.
Rice growing thus has a special place in the social, economic and environmental balance of the Camargue; such balance is sought by all the local players and is affirmed in the Charter of the Camargue Regional Natural Park that covers an area of 86 000 ha, that is to say more than half of the land in the delta.

2.1 – Geographic and Historical study

1 – Geographic data

The Camargue is a delta zone with a total area of 145 000 ha, bounded by the Crau plain to the east and the Costière du Gard hills in the west. Four units make it a homogeneous ensemble (Figure 1): Plan du Bourg in the east (31200 ha), the Gard part of the Camargue (27200 ha) and the Petite Camargue Saintoise in the west (8400 ha) and 'Île de Camargue' or 'Grande Camargue' (78700 ha) bounded by the two channels of the Rhône river. Rice is grown in these four units. However, with about 60% of the crop, 'Île de Camargue' has the largest area under rice.
The landscape of the Camargue has a very slight slope.

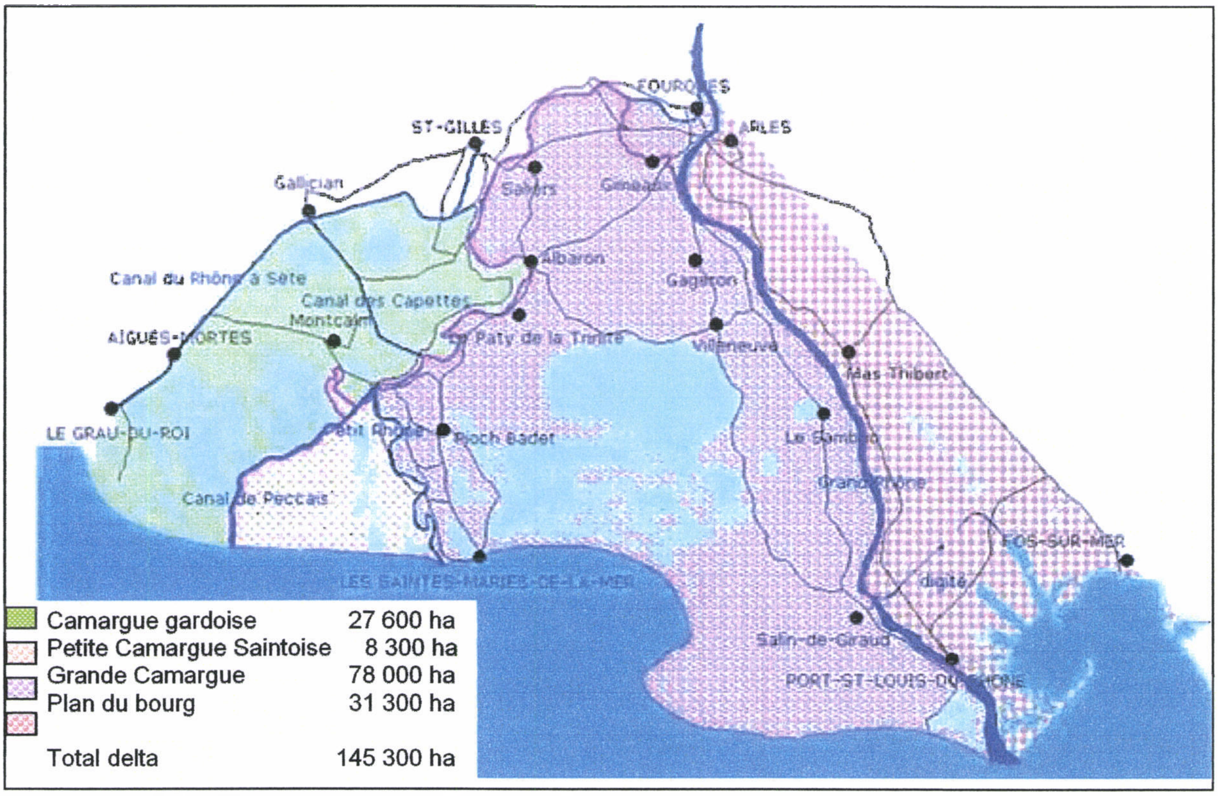


Figure 1. The Camargue areas. Source Parc naturel régional de Camargue

2 – Historical data

Farming in the Camargue has been a very fragile activity since Antiquity. Before large-scale development works were carried out, the Camargue was regularly flooded by the Rhône river and farmers had to flee. Defence from flooding by the Rhône river was organised very early on (Barbier and Mouret, 1991; Durr, 1984).
The first real development works started in the Middle Ages under the aegis of the great monasteries. The forests growing on the riverbank in the north were cleared, depressions were drained and protection against the river was provided by summary embankments. The first real drainage canal was dug in 1508.
King of France, Henri the IVth (14 December 1553-14 May 1610), with expert advice from Sully, published an edict on 23 August 1593, ordering the growing of rice in the Camargue. However, the attempt was unsuccessful. The gradual extension of the Rhone embankments to protect against floods

was accompanied by the creation of an irrigation system required to prevent salinisation and to make it possible to cultivate low-lying land and provide fresh water for humans and animals. The modernisation of the irrigation and drainage system from 1860 onwards was strongly motivated by the introduction of grape vines in the Camargue. In 1864, Etienne Noël Godefoy organised the first rice field for the purpose of desalinating the soil to prepare it for other crops. Rice was not grown primarily for consumption in the Camargue until the mid-twentieth century (1945), but used as a maintenance crop for wine growing and the areas under rice did not exceed 1000 ha (Barbier and Mouret, 1993).

Rice growing only became durably established in the Camargue during World War 2 to replace supplies from Asia and, secondarily, to provide an activity for colonial soldiers obliged to stay in metropolitan France after the defeat of 1940.
The real spread of rice growing in the Camargue began after World War 2 when vineyards were being grubbed up steadily and thanks to encouraging measures associated with the Marshall Plan. Rice growing then expanded strongly until 1965, when French production covered practically the whole of consumption. The area grew steadily from 246 ha in 1942 to 32 500 ha in 1961 (Figure 2). It then decreased until the early 1980s (4 000 ha) after the setting up of the Common Agricultural Policy as this exposed French production to the keenest competitors. Meanwhile, French consumption increased from 1.6 kg per person per year to 3.2 kg. As rice growing had decreased by about 30% between 1970 et 1980, France faced a shortage and had to import 90% of national consumption.

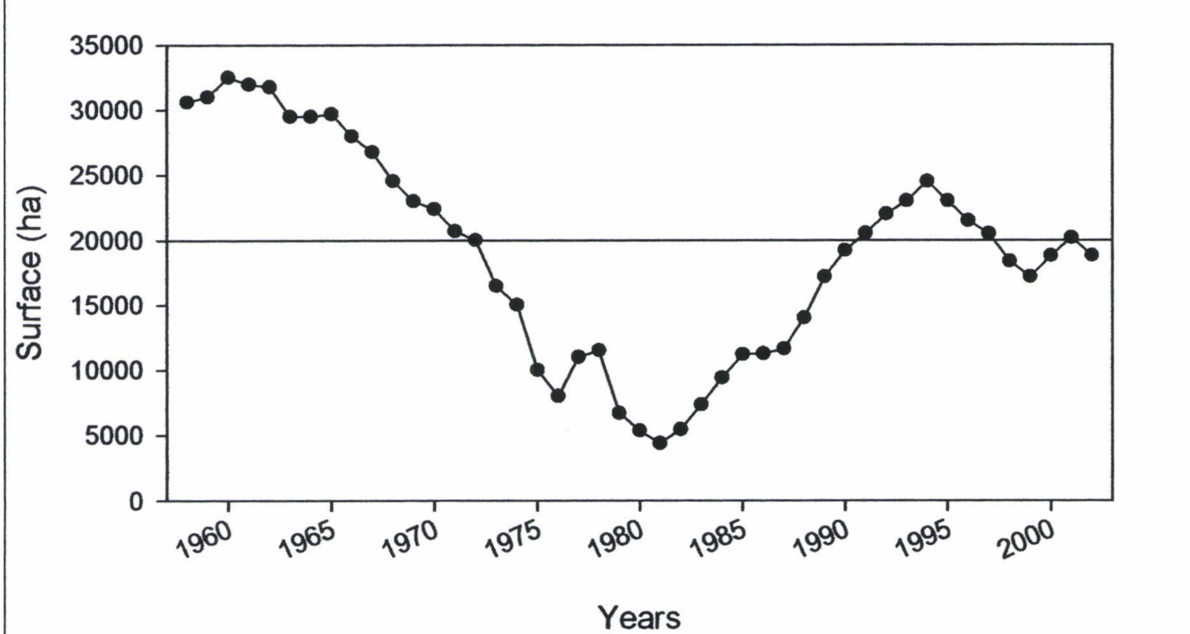


Figure 2. Evolution of the area under rice in the Camargue (France). Soucre CFR

Furthermore, the disappearance of rice led to the abandoning of the hydraulic infrastructure and this had dramatic effects on the environment caused by the rise of ground water with a high salt content. This upsetting of the water balance prevented any farming and imperilled the agriculture-based economy and the environment of the Camargue. A plan to re-launch rice growing was decided in 1981 with help from the authorities. The plan consisted of aid for research and experimental work aimed at increasing production yield and quality, aid for farmers, harmonious cohabitation of rice growing and the environment and the matching of French production to the main market trends. The plan also led to the founding of the Centre Français du Riz (CFR) as a sector co-ordination facility and technical institute. Rice then regained economic interest and was grown on 25 000 ha in 1995. Today, rice growing is once again the main activity of the Camargue with an average area of 20 000 ha but its future depends on its capacity to remain competitive in the face of new economic constraints and in particular the fall in farm prices. It should be noted that 98% (that is to say nearly all) of rice growing is in the Camargue. The remaining 2% is in the Narbonne area.

3 – Soil data

The Camargue region consists of the low delta area and marshland formed by the water of the Rhône and the Durance rivers during floods or successive shifts in course (Bouteyre and Duclos, 1994). Soil texture classification shows that six types of soil are found in the Camargue: clayey, clayey-silty, silty-clayey sandy, silty-sandy-clayey, silty-clayey and sandy-clayey-silty. The lower the land, the richer it is in clays and organic matter. In contrast, more sandy land is found along the alluvial bank of the present or former river channels and on the beach ridges.
The soils are rich in calcareous material (15-45%), giving them a pH ranging from 7.5 to 8.5. The clay content varies considerably (10 to 45%) as does the organic content (1-5%). The lower the elevation of the soil (depressions), the more they are clayey and rich in organic matter. Other soils in the Camargue have formed on old sand dunes, making it possible to grow specific crops (asparagus).
The relative closeness to the sea, the elevation and textures of the soils make them susceptible to rising salinity.

Four main types of cultivated soil are observed (Figure 3):

a/ raw mineral soil
- of alluvial origin: alluvial soils with loamy texture, rich in limestone and not saline even at a depth;
- of marine and fluvio-marine origin: sandy soil that is saline or very saline at a shallow depth,
- eolian deposits: sandy soil that may be saline at a depth

b/ little evolved soil:
- alluvial deposits with loamy-sandy and loamy-clayey texture; this was the earliest cultivated soil;
- eolian deposits: sandy soil with a fairly high organic content

c/ sodic soil
- sodic soils dominate in the Camargue with loamy, loamy clayey and clayey loamy textures. Two types are found; saline soil whose electrical conductivity (EC) is over 7 mhoms/cm and little saline soil whose EC is lower than 7 mhoms/cm

d/ hydromorphic mineral soil:
- this is saline to a greater or lesser degree and found in the low-lying parts of lagoons and marshes. It is clayey-loamy soil.

The effect of submersion on the physico-chemical state of the soil
The covering of the soil with water results in a physical evolution of the entire profile that can be likened to the effect of rain but without the mechanical effect on land cultivated when dry. Porosity is lower in flooded soil but the pores are not rigid; particles move easily under the effect of roots on condition that the land has not been excessively compacted.

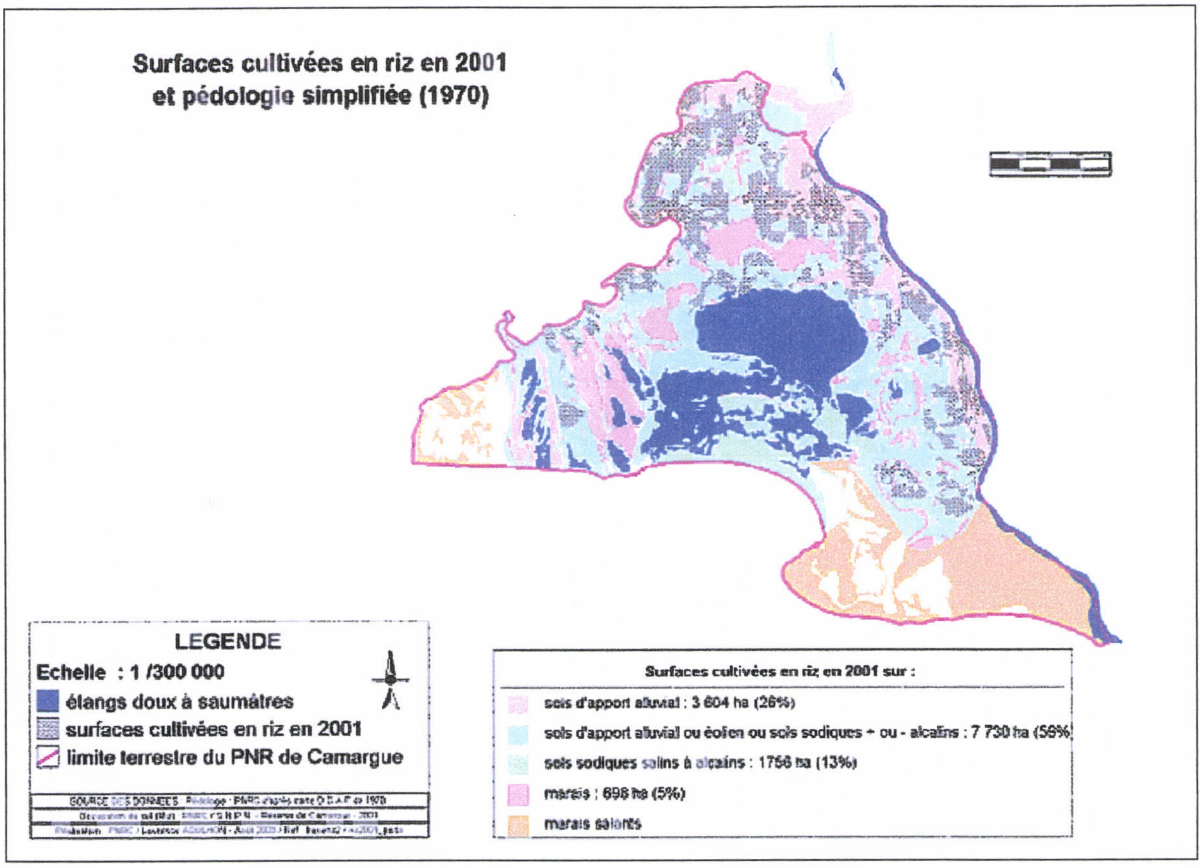


Figure 3 : Soils in Camargue, France. Source Parc naturel régional de Camargue

The accumulation of fine soil at the surface does not form a physical obstacle like plough pan but is nonetheless an additional screen that limits gas exchanges. Thus many rice fields in the Camargue display an accumulation of sulphur dioxide generated by chemical activity in the soil and that forms a blackish horizon that may be from a few millimetres to 0.5-1 cm thick just below the layer of oxided mud.

Inundation of the land enables better release of minerals and regulation of the pH around the neutral point. It limits rising salinity but meanwhile changes microbial activity in the soil by creating anaerobic conditions. Under these conditions, as rice roots require oxygen to function they become dependent of the capacity of the plant to translocate oxygen from the aerial parts to the roots. Such capacity is smaller in the japonica type grown in the Camargue.

Interaction with a comparatively cool climate and the use of japonica varieties means that risks of soil toxicity are accentuated in the Camargue.

4 – Climatic data

The Camargue has a Mediterranean type climate with irregular phenomena. The climate of the Camargue is slightly different to the classic Mediterranean climate; all its features are excessive because the absence of relief means that the prevailing winds do not encounter any obstacles.

The Camargue is at the limit of the Mediterranean climate. It is defined as being sub-humid in the north and semi-arid in the south. Rainfall is generally heavy and of short duration. Rain occurs mainly in the autumn. In contrast, the summer is often hot and dry with the average temperature exceeding 20°C. Autumn and winter are usually mild (Perspectives Agricoles, 1993). The temperature ranges are fairly great. Maximum average temperatures reach 30°C in the summer while the average minimum can fall below 5°C. Conditions are only favourable for rice from April or May onwards.

Precipitation ranges from 620 mm to 540 mm from the north to the south of the delta (Figure 4). It is not sufficient to compensate the high evapotranspiration (some 1300 mm per year), whence an average annual water deficit of 700 mm. The Rhône delta is thus one of the driest regions of France.

The Camargue is also constantly swept by strong winds resulting from the meeting of Mediterranean and Atlantic air masses. Examination of the wind system shows that the Mistral (a north wind) is clearly the prevailing wind. It accentuates the Mediterranean character of the Rhône delta. Blowing more than 200 days a year, it increases evaporation and contributes to the overall water deficit in the plain of the delta (Barbier and Mouret, 1992).
The scarcity and irregularity of precipitations, strong insolation, high average summer temperatures and strong winds result in a deficit in the water balance.

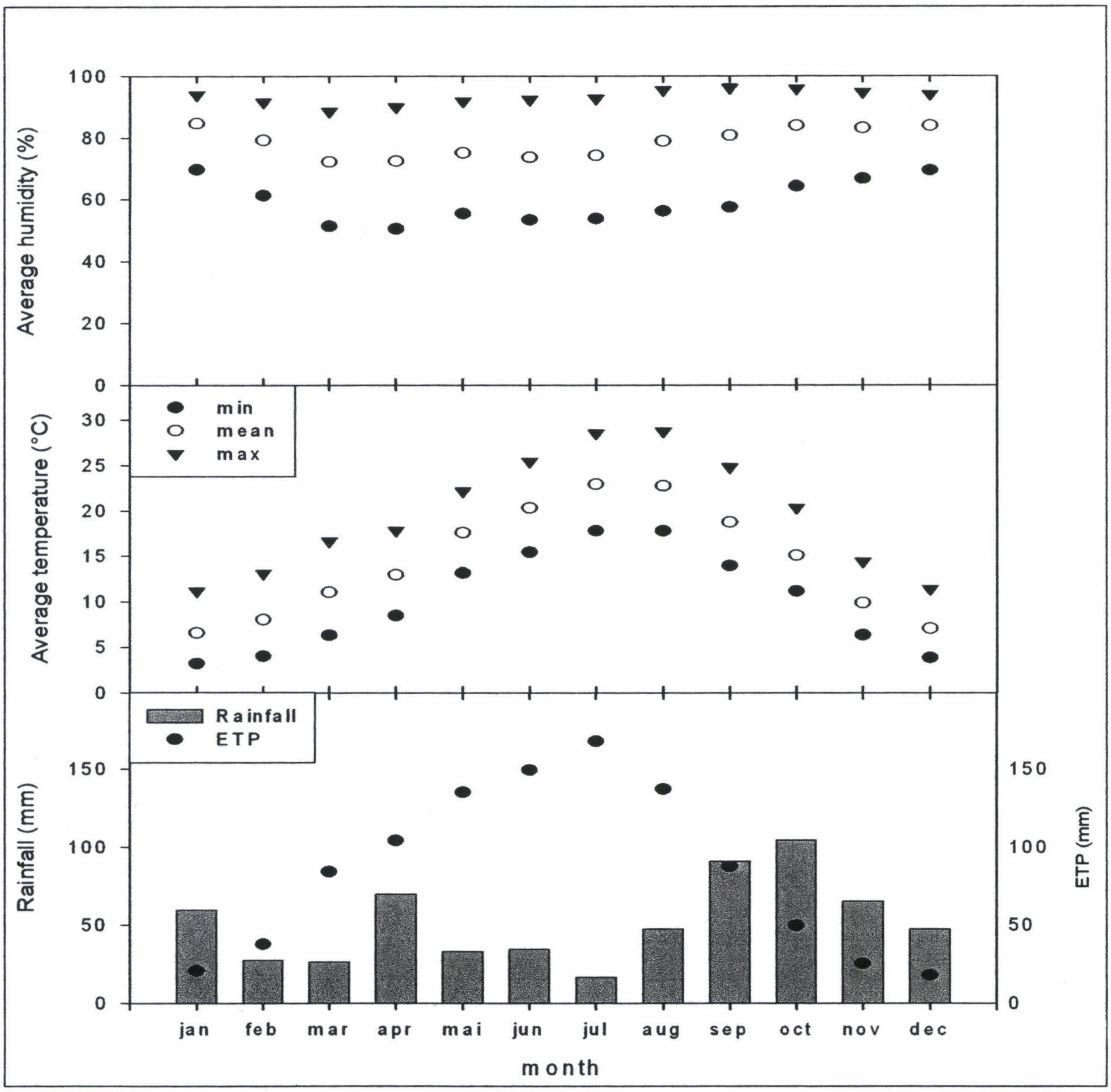


Figure 4. Mean climatic data for 1999-2002 period in Camargue, France

5 – *Physical determinants*

2.5.1 Water (hydrology)

In the Camargue, distinction is made between two major features: surface water and continental water:

- *surface water*

The Rhône river is the major source of fresh water, flowing for 812 km, of which 290 km is in Switzerland. North of Arles, it divides into two channels: the 'Grand Rhône' that flows towards the east of the delta and the 'Petit Rhône' to the west. The 'Grand Rhône' is 50 km long, 150 m wide at Arles and 400 m wide at the estuary; it is 8 to 10 m deep and the average flow is 1400 m^3/s. The 'Petit Rhône' is 60 km long with a stream flow about a tenth of that of the 'Grand Rhône'. Lagoons cover large areas in the lower Camargue (Vaccarès lagoon has an area of 6400 ha) and in the 'Petite Camargue' in the Gard department. The water is saline, with strong variations of salinity in the summer. The volume of water concerned is small.

- *continental water*

The groundwater is very close to the surface of the soil. Heterogeneous shallow ground water is found in the fine surface sediments where permeability is very low and variable.

2.5.2 Salt

Samples have been taken with a salinometer in both summer and winter in a representative sample of water-covered zones in the delta (Parc Naturel Régional, 2004).

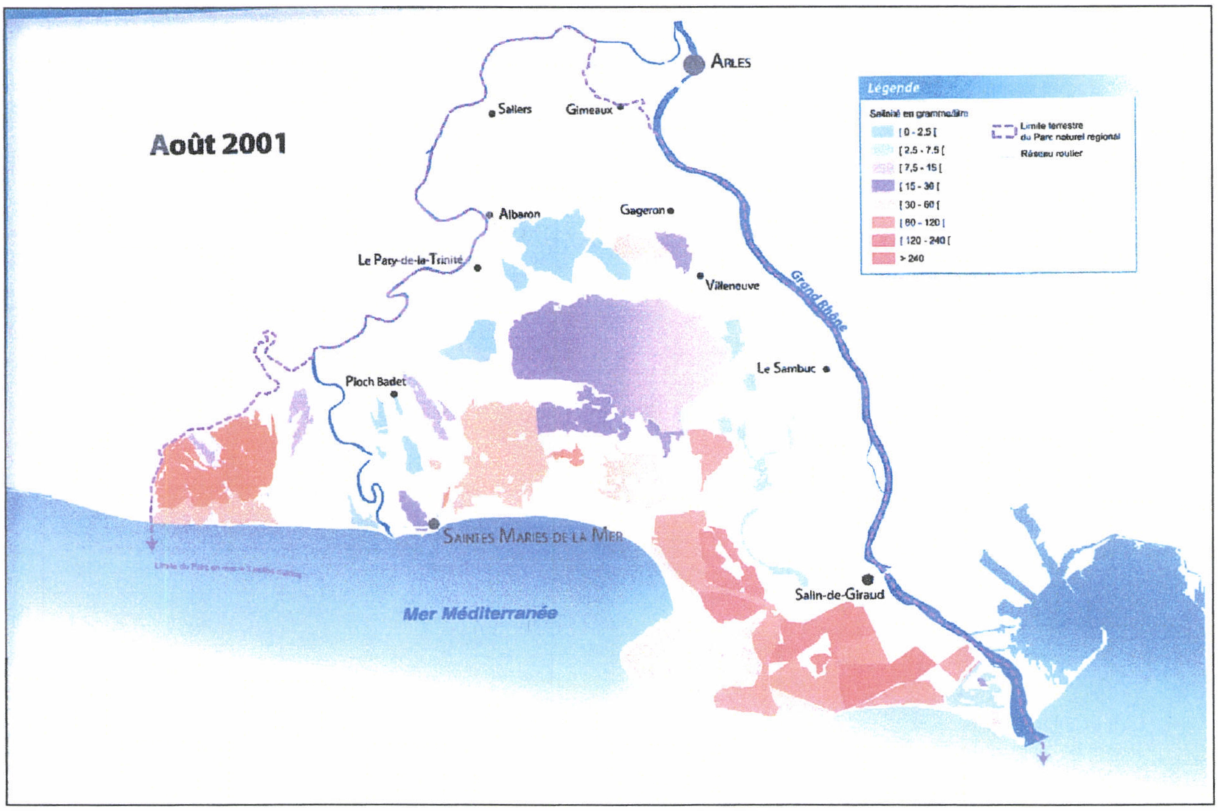


Figure 5 : Water salt content, Camargue 2001. Source Parc naturel régional de Camargue

Figure 5 shows a salinity gradient is observed in the ground water and runs from north (0.5 g/l) to south (2 g /l). The salt in underground and subsoil water is of marine or lagoon origin. The subsoil in the southern half of the Camargue - recently reclaimed from the sea - has a high salt content. Some

areas in the southern half are below sea level and the ground water sometimes has higher salt concentrations than sea water (36 g/l).
The existing strong deficit in the water balance enhances the rise of saline ground water by capillarity, especially as rainfall frequency is highest in autumn when evaporation is limited.
This strong water deficit would result in the complete sterilisation of the soil without water from the Rhône making up the shortage naturally (by uncontrolled floods) or artificially (by irrigation after the embanking of the river).
With these saline soils, the alkalinity found (pH 8 to 8.5) is the result of the presence of calcium carbonate.

6 – Information on land use; a mosaic of environments

Fluvial dynamics and the action of the sea have created special environments. The living beings that live there have to adapt to the water regime (flooding or drought, etc.), to the salt content, sediments and soil texture that are very different from one point in the delta to another.

The simplified map of land use in the Camargue shows the combined effect of physical factors on the geographical distribution of environments (Figure 6). Cultivated areas are in land where farming is possible thanks to man's mastery of the inflow of fresh water (Parc Naturel Régional, 2003). The cropping zones thus developed more easily close to the two channels of the river. They are also found on former alluvial banks, land where salt is at a greater depth.

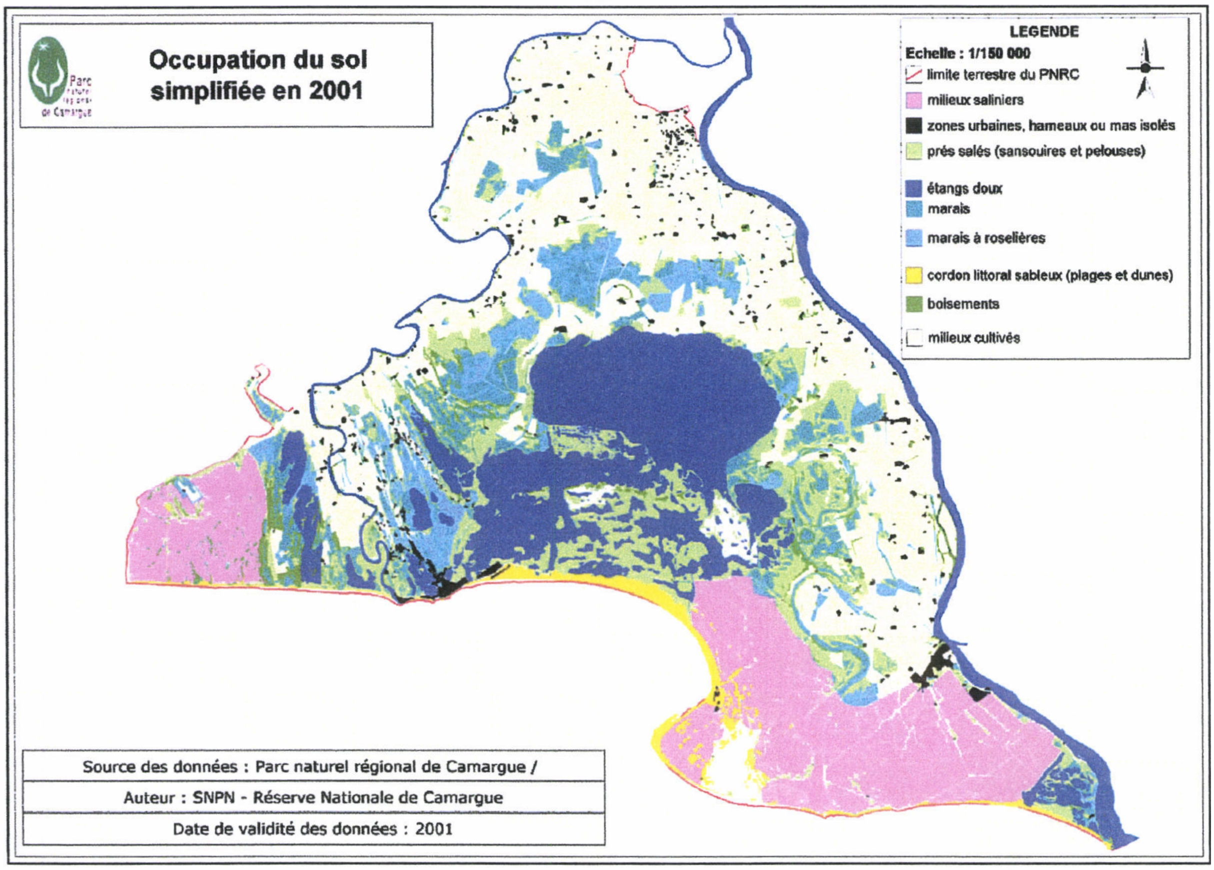


Figure 6 : Simplified map of land use, Camargue 2001. Source Parc naturel régional de Camargue

The cultivated area totalled 33,000 ha in 2001 and included 20,000 ha of rice. The remaining 59,300 ha of delta area consists of two main types of natural wetland habitat. Temporary wetlands with fresh

to brackish water (marshes, ponds, *sansouire,* etc.) cover a total of nearly 20,400 ha and permanent wetlands (lagoons, etc.) cover 28,300 ha.
Cultivated environments, temporary wetlands and permanent wetlands display a concentric layout with lagoons in the heart of the delta. The marshes and *sansouires* surround the heart, rather like a shield, and push the cropped zones towards the river channels.

The result of this process of fashioning of the Camargue has produced a compartmentalised landscape, a mosaic of higher and lower ground whose difference in elevation is no more than 1 or 2 metres, but this governs the depth of the ground water, the rates of salinity and soil hydromorphy and texture. The pattern reveals two main geomorphological ensembles—an Upper Camargue that is mainly of fluvial origin and a Lower Camargue where sedimentation was initially marine and is of the lagoon-lake type.

Nevertheless, this very general approach to the spatial organisation of the main types of environment does not conceal the geomorphological complexity (alluvial banks, sedimentary depressions, dune ridges, etc.) revealing a clearly visible mosaic of environments in which cultivated land is frequently interwoven with natural areas.

7 – The need to conserve irrigated farming in the Camargue

Agriculture in the Camargue has had to adapt to the inherent constraints of marked soil hydromorphy, climatic extremes and the presence of salt. For these reasons, a large quantity of water (300 million m^3 in an average year) is taken in from the Rhône at the estuary and mainly used in rice growing.
Indeed, the presence of rice in the Camargue is a condition for the introduction of other crops in the cropping plan (Figure 7). Rice is thus assigned to a given area and becomes the main crop when the physical constraints are strong. Rice growing thus desalinates land for the requirements of other crops. The main cropping system is a rotation consisting of rice – durum wheat or rice – durum wheat – alfalfa. Rice leaches out the salt and wheat breaks the weed cycle in rice. According to the cropping year, the area under rice varies around 20,000 ha in the Camargue. The other cereal and forage crops alternate with rice. The importance of these crops varies according to the climatology for a given year.

Thus in most cases rice is grown on 55% of the total area of an average rice-oriented cereal farm in the Camargue. The other parts are used for dry crops (30%) and the final 15% consists of managed natural areas (used for livestock farming, hunting, fishing, etc.).
The area under rice is obviously less representative (23% of the area) in farms combining cereal growing and livestock whereas natural environments are dominant at up to 60%. Rice growing has proportionally a special position in both main types of farm.

It is therefore advisable to conserve these distributions of area that ensure both the economic stability of farms and the maintaining of the presence of the natural wetlands associated with them.

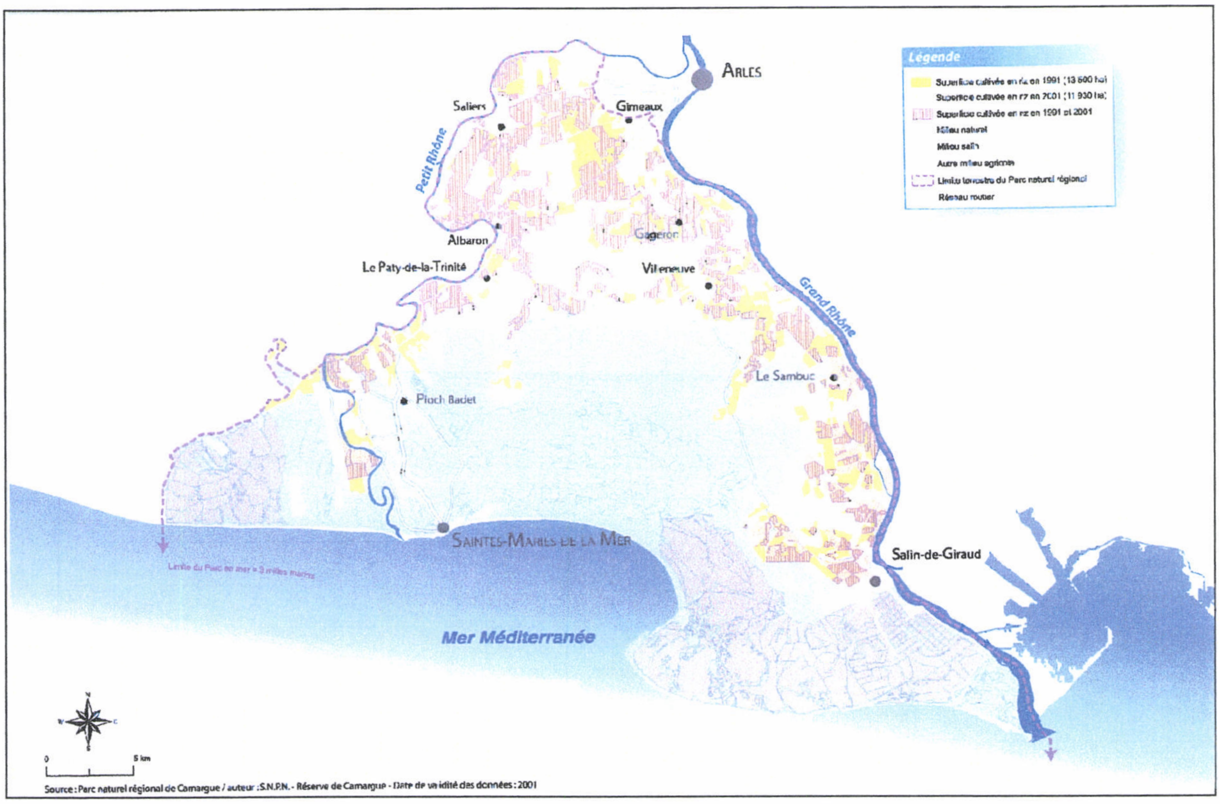


Figure 7 : Rice fields, Camargue 2001. Source Parc naturel régional de Camargue

8 – Organisation of water management

Since the construction of the Camargue dykes, the inflow of water from the Rhône has been controlled by an extended, ramified irrigation system.

Flood irrigation is a necessity for agriculture in the Camargue as it reduces the salt content of the soil and makes up for the deficit in the water balance of the delta.

Management of the inflow of fresh water is of two types (Parc Naturel Régional, 2004):

- *private management* covering 40% of the quantities let into the Camargue. This is handled by individual landowners who take water directly from the Rhône. This type of management mainly concerns the farms close to the two river channels;
- *collective management* accounting for 60% of the intake to the delta zone. For this, farms have grouped to form irrigated areas in which the maintenance and operation of the hydraulic facilities are shared.

The status of *Association Syndicale Autorisée* or *Association Syndicale Forcée* (ASA or ASF) makes it possible to set up water rights and fees that must be paid by every farmer with membership of the association.

In all, nearly 20 irrigation ASAs covering perimeters with areas ranging from 200 to 2,000 ha manage the irrigation of 20,000 ha of irrigated crops in the Camargue.

Rice growing is the agricultural activity that uses the most fresh water in the Camargue. Indeed, the rice vegetative cycle requires 10,000 m^3 per hectare per year. To this are added the losses by percolation and 'leakage' from irrigation equipment, estimated at 10,000 m^3 per hectare per year and also the water required for dewatering and rinsing the rice fields. A total of about 25,000 m^3 water per ha per year is used in rice growing.

The rice growing period (April-September) accounts for 97% of the total volume pumped from the Rhône in a year. During the peak water requirement period for rice (July-August), intake from the river is approximately 200 million m^3, that is to say half of the annual intake.
Although the irrigation network is strongly associated with agriculture, the drainage system concerns all the activities and environments of the delta. While the irrigation system brings in about 400 million m^3 of fresh water each year, the drainage network discharges 200 million m^3 into the sea, either directly or via the Rhône. The Camargue drainage system handles both agricultural and rainfall runoff water.
Drainage management is entirely collective. Organised via associative management organisations, it ensures the maintaining of surface water levels compatible with most activities. The ten main drainage basins located throughout the whole of the Rhône delta, thus discharge both surplus agricultural water and rainwater.

2.2 – Cultivation conditions

1 – Constraints and advantages

The main constraint for rice growing in the Camargue is the climate. The area is in the extreme north of the rice production zone and cold and wind are the main hindrances for the crop (Barbier and Mouret, 1993; Barbier and Mouret, 1992; Durr, 1984).
Indeed, low temperatures (of around 10-12°C) can continue throughout May, disturbing the installation of the crop by delaying emergence and favouring seed rot. Likewise, late sowing may be compromised by substantial falls in temperature and by heavy rainfall in the autumn.
Wind is also harmful at the beginning of the season; it makes waves in the fields, shifts the seeds and lifts the soil particles that cover them. The seeds germinate with difficulty when placed under such anaerobic conditions (low oxygen content). These water movements can also uproot seedlings when these are only lightly rooted. Furthermore, water turbidity considerably reduces the light reaching the plants during windy periods (Barbier, 1994).
Wind can also cause water stress even though the crop is continuously submerged. Strong, drying winds also cause a reduction in leaf area.

In the face of these constraints, Camargue rice growing nevertheless has substantial advantages. The land is flat and the soil deep and rich in clay and loam. It benefits from unlimited quantities of fresh water from the Rhône and sunshine is not a limiting factor. Furthermore, strong, drying winds (Mistral) help to limit infestation by fungal diseases. Finally, technical skills have developed considerably with yields increasing from about 4 tonnes per ha in the 1960s and 1970s to 6 tonnes per hectare today.

In spite of this, the rice growing profession has new difficulties. Rice growing is very expensive. The recent decrease in the price of rice thus makes the situation delicate again. When to this is added the fact that the Camargue is also a regional natural park containing a national fauna and flora reserve, making it necessary to allow for increasing ecological pressure in rice growing, it can be seen that the crop is in need of adaptation and must meet a new challenge—that of reducing production costs and remaining compatible with the conservation of the natural environments in the Camargue.

2 – Crop management sequences

Camargue rice growing is marked by two main types of constraint, water-related constraints and temperature. As the crop is grown under conditions of submersion, the amount and distribution of rainfall is relatively unimportant. However, total radiation and temperatures are determinant conditions for growth and development (Barbier and Mouret, 1992).

Because of the climatic conditions and strong heat requirements (zero vegetation towards 12-13°C, flowering requiring 21-22°C and a cycle lasting 140 to 160 days), the Camargue rice cropping calendar is not flexible (narrow cultivation window). It is difficult to sow before 20 April. Sowing performed after 10 May risks temperatures that are too low for flowering in August or the strong Mediterranean climate rains from the end of September and October until harvesting (Table I).
Germination is usually very difficult. Whether sown before or after inundation, rice grains are treated with a wetting agent and sown on the surface of the soil. They germinate and emerge under several centimetres of water. Cold and wind are the main enemies here (see above). The sowing-emergence phase is doubtless that with the most constraints and the greatest difficulties.

Table II. Cultural calendar

Dates	Stage of rice	Cultural operations
After the harvest: from November to March		Burning off stubble: limiting residues Stubble ploughing: disc harrowing Deep tillage: ploughing or tine tools Levelling, optimum management of water depth
April		Bottom dressing, average: N=50 U, P=60 to 80 U, K=60 to 100 U. Preparation of seed bed: offset disc harrow and/or rotary harrow, roller
20 April to 10 May		Sowing: several options: - in water: broadcast sowing with a centrifugal fertiliser spreader, - dry: broadcast, in seed holes, in rows. seeds are always sown at the surface of the soil.
20 April to end of May	Before sowing, swelling or the start of emergence	Herbicide treatment against barnyard grass Algicide Vermicide
End of May/early June	From 1 leaf From 2-3 leaves Start of tillering (3-4 leaves)	Post-emergence herbicides to control *Echinochloa*, anti Cyperaceae First nitrogen top dressing: average 50 units
Early July	Tillering in full progress. Start of stem elongation or '1 cm ear' stage	Herbicide to control Cyperaceae Second nitrogenous top dressing, average 50 units
End of July to early August	Start of heading	Treatment against rice stem borer (*Chilo suppressalis* Walker)
Mid-September to end of October	Maturation	Harvesting

Rice growers drain the fields one or several times between emergence and tillering and the soil becomes like liquid mud. Management of this is very complex in practice as it must meet contradictory requirements.
Draining the field oxygenates the soil surface, enhancing seed germination, facilitating the rooting of

seedlings and slowing the growth of algae and certain fungi. But the water is no longer there to play its role of heat buffer that is essential during cold, windy weather, or to act as a regulator of salinity (rice is indeed fairly sensitive to salt, in a category between wheat and maize). The length of the drained periods must therefore be limited (8 to 10 days) and their setting must be adapted to herbicides and nitrogen applications in order to draw the most from them.
Flowering must be early enough (end of July – beginning of August) to benefit from favourable conditions of temperature and sunshine. If this is not the case, numerous spikelets become sterile.
Too high a temperature, sometimes combined with drying wind, during grain filling and maturation affects grain quality (as in 2003). In addition to increasing the risk of lodging, wind dries the grains too quickly. Mistral is feared all the more at the end of the cycle as farmers drain the rice fields to be able to harvest on dry ground; this prevents harming the rice field by rutting that affects levelling. The first autumn rains may also disturb harvests by aggravating lodging and preventing the fields from drying. The end of the cycle is accompanied by increasing frequent problems of pyralid attacks (because of increased monoculture) and *Sclerotium* (fungi causing stem rot) that affect harvest quantity and quality. A survey revealed variation in the cultural techniques used. This heterogeneity is partly related to the types of land and crop sequences used and to the labour and equipment available.

2.2.1 Cultivation

The straw is burned off after the harvest to reduce crop residues and stubble ploughing performed with an offset disc harrow. This is followed by ploughing to prevent the formation of small clods; the soil is thus loose and little compacted. A minimum of compaction is required for good root anchorage (apparent density around 1.6) and better availability of minerals (Kar and Ghildal, 1972; Kar and Varade, 1975).

Land planing is performed using a laser-guided levelling blade to achieve optimum management of water depth. The soil is scarified (discs) or ploughed during the winter. Levelling is performed at the end of the winter (harrow + discs). Levelling planing is performed using a blade before intake of water in March.

Sowing
Sowing is performed at the end of April using 180 – 250 kg seed per ha according to the variety, with an average of 230 kg. These large seed doses are used to solve the problem of heterogeneous emergence. The seed is either treated with a wetting agent or pre-germinated (48 hours soaking + 48 hours drainage) to prevent them from floating at sowing. Seed is broadcast with a centrifugal seeder.
The quantity of seed is very large in relation to the number of seedlings. It is estimated that the average emergence rate is about 30%.

Fertilisation
P_2O_5 and K_2O fertilisation is fairly variable. Camargue soils are known for their low assimilable phosphorus content and P_2O_5 application is particularly high. Nitrogen is applied in the form of ammonia alone. Doses are around 120-140 units of nitrogen, except when the preceding crop is alfalfa (0-50 units). A bottom dressing (50-60-70 units) is applied by 30% of rice growers.
The first top dressing is applied at the start of tillering at the 3-4 leaf stage (40-50 DAS) with 50 units of nitrogen in urea form.
The third dressing is applied at stem elongation (75-80 DAS) and also consists of 50 kg nitrogen in the form of urea.
Some rice growers split applications to adjust the dose to the number of plants tillering and to weather conditions.

After the problem of emergence density, the degree of infestation with weeds and pathogens is the main factor accounting for yield variations. The submerged environment enhances the installation of a specific, very competitive weed flora and pests.

2.2.2 Weed management

Weeding is delicate under flooded conditions and its effectiveness is uncertain. Herbicides are the only way to limit the spread of weeds (Mouret et al., 2001; Mouret et al., 2003; Thomas, 2004).
For Camargue rice growers, the main weeds targeted in cultural operations are listed below.

Weed rices
Weed forms of the same species (*Oryza sativa*) as cultivated rice, these were reported in 1986 (SANON, 1986) but had appeared in the Camargue well before. One or more characters distinguish them from cultivated rice in the field (vigour of emergence, plant height, tillering capacity, earliness, grain format and aristation, node colour, hairiness, etc.). Their main characteristic is their strong tendency to shed seed; this means they cannot be harvested and they infest fields rapidly (Streito, 1992).

Echinochloa (barnyard grass):
In the Camargue, the term *panisses* (barnyard grass) covers all the *Echinochloa* including the main species *Echinochloa crus-galli*. These grasses may display considerable morphological variation and rice growers often make a distinction between white and red ecotypes according to the colour of the base of the stem and on which the efficacy of certain herbicides is different.

Cyperaceae
These include several species characteristic of flooded environments, the most frequent being *Scirpus maritimus*, whose reproduction is essentially vegetative, and also *Scirpus mucronatus* and *Cyperus difformis*.

Herbicides available
Rice growers have a choice of 12 authorised active substances (or combinations of active substances) belonging to various families (Table II):

- aryloxyacids ('plant hormones'): 2,4-MCPA, dichlorprop-P
- amides: propanil (1962)
- thiocarbamates: molinate (1965)
- chloroacetanilides: pretilachlor (1988 with fenclorim, 2002 alone)
- benzothiadiazone: bentazone (towards 1980)
- sulfonylureas: bensulfuron-methyl (1990), azimsulfuron (1999)
- aryloxyphenoxy-propionates ('Fops'): cyhalofop-butyl (2001)
- oxadiazoles: oxadiazon (2002)
- cyclohexane-diones: cycloxydime (2004)

Application of herbicides is the main weed management technique in conventional rice growing (97% of the area under rice in 2004).
However, weeds are managed in an integrated manner as much as possible. The features are as follows:

- crop rotations

The area under rice in Camargue rice farms forms an average of only 50% of the usable agricultural area, with the rest being used for durum wheat (20 %), forage crops (20%) and more marginal crops (oilseeds and maize). Rotations, where these are possible (soil not saline, land accessible in the autumn for sowing durum wheat), help to reduce weed infestation of fields when rice is grown in them again. The use of specific cultural practices such as flooding fields as soon as possible after the durum wheat has been harvested in order to make the weeds germinate and then die (wild rice, barnyard grass) is a further control technique during rotations.

- tillage

Growers find it beneficial to perform shallow tillage in fields infested with wild rices, leaving the latter to germinate in the following spring if they plan specific chemical control or if they are to grow a different crop. In contrast, ploughing in the seeds is beneficial if they plan to grow another rice crop with no specific control of wild rice.

Table II. Active substances and commercial products authorised and available for weed management in rice growing in France

Active substance Name and concentration	Trade name Name (distributor)	Application dose
oxadiazon (250 g/l)	Ronstar (Bayer CropScience)	2 l/ha
pretilachlor (500 g/l)	Rifit (Syngenta Agro)	2 l/ha
cycloxydime (100 g/l)	Stratos Ultra (BASF Agro)	4 l/ha
molinate (750 g/l)	Ordram Stauffer (Certis) Molinam (Sipcam-Phyteurop)	4 to 6 l/ha
pretilachlor (240 g/l) + fenclorim (120 g/l)	Sofit liquide 240 EC (Syngenta Agro)	4.2 l/ha
cyhalofop-butyl (200 g/l)	Clincher (Dow AgroSciences)	1 l/ha (+ wetting agent)
propanil (360 g/l)	Stam F34-A (Dow AgroSciences)	7 to 10 l/ha
azimsulfuron (50 %)	Gulliver (DuPont)	40 g/ha (+ wetting agent)
bensulfuron-methyl (60 %)	Londax (DuPont)	100 g/ha
bentazon (87 %)	Basagran SG (BASF Agro SAS) Adagio SG (Sipcam-Phyteurop)	1.1 to 2.2 kg/ha
bentazon (333 g/l) + dichlorprop-P (233 g/l)	Couppel (BASF Agro SAS)	3 l/ha
2,4-MCPA (400 g/l)	U 46 M BASF (BASF Agro SAS) Callio M400 (Calliope) Ugecormone (Sipcam-Phyteurop)	0.4 to 0.6 l/ha

- choice of variety

The competitiveness of rice varieties with regard to weeds is an important criterion for growers who therefore integrate initial vigour, tillering capacity and stem height in their choice of variety. Thus varieties with good emergence characteristics and tall stems (Ariete, Ruille, etc.) are sown in priority in fields infested with wild rice. The better zones are reserved for the less competitive varieties (Thaïbonnet, Gladio, etc.).

2.2.3 Pest management

Knowledge of the present phytosanitary situation in Camargue rice growing makes it possible to identify diseases caused by pests that have a significant effect on rice growers' profit margins. This can be gauged by the decrease in yields, decrease in production quality or an increase in production costs

related to pest problems. In addition to clearly identified phytosanitary problems, the possibility of the appearance of new diseases requires a permanent watch.
Among phytosanitary problems recorded in the Camargue, damping-off disease, *Sclerotia* diseases of straw and blast disease of rice are the three main constraints to be controlled.

Damping-off is probably caused by complex interactions involving pathogens. The pathogens responsible are known and fungicide active substances that are effective *in vitro* have been identified. Nevertheless, their application in the field has been found to be poorly and irregularly effective according to the year, the site and varieties. The reasons for this ineffectiveness must therefore be sought and the use of other control methods also envisaged.

Stem rot is a recurrent problem in the Camargue. The use of tolerant varieties seems to be a suitable control method. However, tolerant varieties do not always have the agronomic characteristics sought by growers. Breeding for tolerance to stem rot is therefore an objective of varietal creation and selection programmes. The difficulty lies in the lack of a reliable method for early evaluation of tolerance.

Epidemics of blast disease of rice are irregular in the Camargue but symptoms of the disease are observed each year, showing that the pathogen is present on a permanent basis. Yield losses of 100% have even been observed recently in a variety known for its susceptibility to the disease. In this context, the use of resistant varieties is an effective method with no extra cost for the rice grower. Resistance to blast is an objective in ongoing breeding programmes. However, evaluation is performed on advanced generations thanks to tests in greenhouses. Earlier evaluation in the field would be desirable. Characterisation of the pathogen populations has been initiated and the study of the resistance of varieties grown in Europe has provided information for consideration of the strategies of use of resistance. Closer knowledge is nevertheless required for the development of varieties possessing lasting resistance.

Pyralid causes fairly substantial losses in rice growing. This borer colonises tillers and halts the grain filling process; the stems become susceptible to lodging, the panicles wither and become sterile.

In other seasons, pest pressure from these diseases has sometimes resulted in very occasional damage and generally the total absence of symptoms. This feature of the Camargue with regard to irregular pest constraints has two results:

- the absence of pesticides registered for control of these pests whose presence is too uncertain;
- the impossibility of field selection for tolerance to these pests except in years of strong pest pressure; this is not satisfactory since such an occurrence can call several years' work into question.

3 – Organic cultivation

Today, economic constraints (a substantial decrease in the price of paddy rice) and strong environmental pressure are leading to a crisis situation in French rice growing. The development of organic rice growing, whose value added and specifications match the constraints just mentioned, is a form of diversification undertaken by several rice growers who devoted 500 ha to this in 1999 (Lardon *et al.*, 2000). After a period of strong increase (1995-1999), conversion to organic farming has since stagnated. The area farmed in this way has stabilised at about 5%. This is doubtless because of the uncertainties associated with this type of farming.

An agronomic assessment performed in 1998 and 1999 on the basis of the agronomic monitoring of land under rice revealed that paddy rice yields varied from 12 q per ha to 70 q per ha (Mouret *et al.*, 2000). The study showed that weed infestation was the main limiting factor for yield.
Conventional rice growing in the Camargue is intensive with direct seeding and practically permanent submersion. Water plays a determinant role in heat and by considerably reducing the soil sodium level (Mouret, 1988). Furthermore, this aquatic crop contributes to the development of weed flora (Streito, 1992) consisting mainly of Gramineae (in particular *Echinochloa* spp.- barnyard grass) and Cyperaceae (*Scirpus* spp. and *Cyperus* spp.), whose development is subject to ecological conditions—especially temperature—that are less demanding than for rice. Mechanical control of these weeds requires a change in the conventional sowing technique (seed broadcasting); sowing must be performed in rows with sufficient interrow spacing for the passage of a weeding machine.

Problems
Sowing remains a considerable problem. It is handled as in conventional rice growing by a high dose of seed.

Weed management
Weeds are the main limiting factor for yield in conventional intensive rice growing. Because of the lack of references and technical solutions, this constraint is strongly accentuated in organic rice production. The weeds that are most difficult to eliminate are the Gramineae closely related to rice—barnyard grass and wild rice. Infestation develops, especially in monoculture, because their earliness enhances seed shedding before the harvest and it is difficult to perform successful herbicide treatments. Manual weeding used to be performed in the Camargue on replanted rice but is only used today by some growers of organic rice.

4 – Yield

As shown in the figure 8 below, yields have increased significantly since the middle of the last century. Yields have increased by nearly 50% since the plan for the re-launching of French rice growing (1980). However, with an average of 55 to 60 quintals per hectare, it is less than the yields achieved in neighbouring countries, in particular because of the climatic constraints of the Camargue.

In order to compete with the other European producers and the rest of the world (GATT agreements of 1994: lowering of European customs barriers and decrease in aid for farmers), rice growers have undertaken to highlight the quality of their product, a completely different attitude to the previous quantitative, productivist approach. They were awarded conformity certification in 1998 and protected geographical indication (PGI) in 2000. There is thus a desire to find a suitable, reliable commercial outlet for the small production of the Camargue.

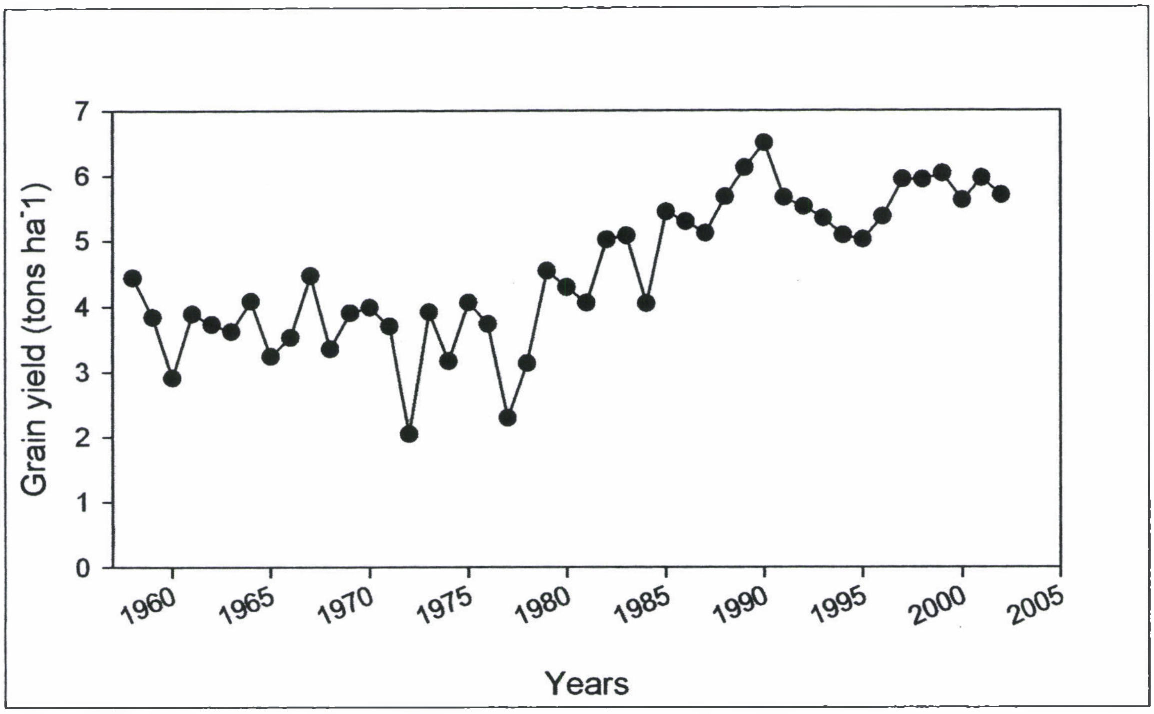


Figure 8. Rice grain yield evolution in the Camargue (France). Source CFR

5 – The rice grown in the Camargue

Two morphological types of rice are grown in the Camargue: japonica, with fairly short grains (round, medium or long A) and the indica type with very long grains referred to as long B.
The agronomic qualities of these varieties are appreciated for their resistance and suitability for poor soils.

Long A is currently the most commonly grown rice (Figure 9). Round and medium grain rices are dwindling to the advantage of long B (including naturally perfumed rice) that is more to the taste of consumers today. Indeed, the consumption of long B rice has increased from 56.1% of French rice consumption in 1990 to 74.5% in 2002, that is to say 182 500 t (source: European Union).

Among the japonica rices, round rice consumption has fallen markedly from 67% of national consumption in 1958 to only 9% in 1994.

French rice consumption is considerably greater than Camargue production. The latter totalled 105 994 t of paddy rice (107 262 tonnes in France as a whole) while consumption was 245 000 t white rice equivalent, that is to say about 408 333 t of paddy rice: 26% of requirements.

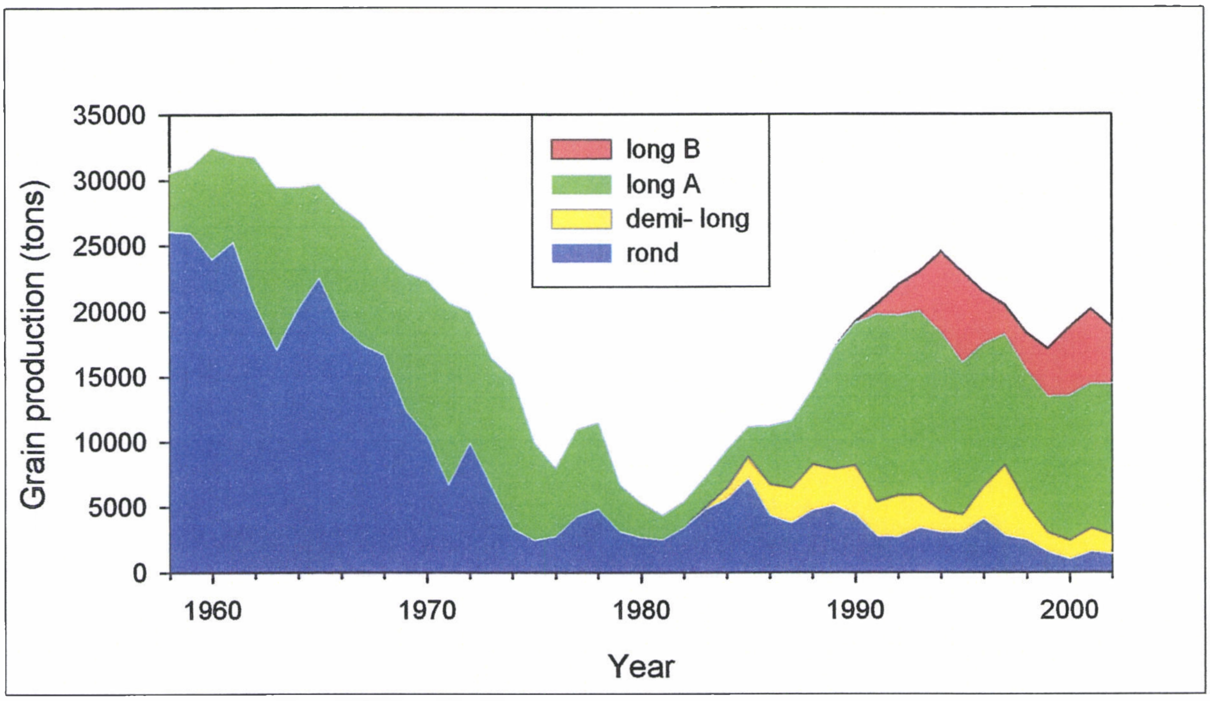


Figure 9. Grain types produced (Camargue). Source CFR

Thanks to research carried out, in particular at the Centre Français du Riz, and to match consumer requirements, Camargue rice growers have concentrated production on long B rice and, since 2000, a naturally perfumed variety suited to the climatic conditions of the Camargue. Table III shows the production distribution in year 2002. Perfumed rice is still very little represented, 1.3% in 2004

Table III : rice type production distribution in Camargue, 2002.

Grain type	Production (tonnes)	Proportion (%)
Round	7 629	7.12 %
Medium	6 838	6.38 %
Long A	70 051	65.37 %
Long B	22 649	21.13 %
TOTAL	**107 167**	**100.00 %**

Source : CFR

Based on an introduction programme, the Camargue collection consists of about 300 varieties from temperate rice growing countries and above all from Italy as many rice growers came from there.

The lowland rice breeding programme for Mediterranean France is aimed at producing varieties suited to the difficult environment of the Camargue in order to meet demand from growers (steady production and yield level), processors (suitability for milling) and consumers (culinary and taste qualities).

The climatic conditions of Mediterranean France lead to awarding priority in crop management to two characteristics:

- emergence ability under anoxic conditions and early flowering. The best results are obtained with varieties displaying vigour at emergence, thus enhancing good pollination of spikelets at flowering during the period when the weather is most favourable (20 July to 10 August);
- pest tolerance. Stress has been laid on breeding resistant varieties and it should be possible to transfer high-resistance genes by crossing with susceptible varieties;

- the commercial quality of the grain and the demand for new products. The world rice market is now very varied for better satisfaction of consumer tastes. Although round-grain rices are still grown in the Camargue, slightly sticky rice with long, slender grains is a favourite among consumers.

3.1 – Organisation of rice production

Since the plan for re-launching rice, growers have been organised as the Syndicat des Riziculteurs de France et Filière. More than 80% of rice farms in the Camargue belong to this association. Nearly 300 growers thus rely on its competences for achieving results in the design and implementation of projects for drawing more from rice and promoting their work.
The policy of the rice growers' association takes into account the environmental context of the Camargue both as a component of the technical functioning of farms and as a feature to be exploited through a product quality policy.
The Centre Français du Riz (CFR) set up at the end of the 1970s is a scientific body that conducts experimental programmes to improve yields, to reduce the impacts of pesticides and to seek new crop management sequences.

1 – Rice production in the Camargue

The rice production area in the Camargue farming area is in the Bouches-du-Rhône department (the Rhône delta and the area east of the Grand Rhône in the communes of Arles, Les Saintes-Maries-de-la-Mer and Port-St-Louis-du-Rhône) and the Gard department (the part of the Petite Camargue west of the Petit Rhône in the communes of Aigues-Mortes, Fourques, Le Cailar, Vauvert, Aimargues, Saint-Gilles, Beaucaire, St-Laurent-d'Aigouze, Le-Grau-du-Roi and Bellegarde).

3.1.1 Camargue rice farms

In 2000, the average total area of rice farms was 220 ha with an average usable agricultural area (AA) of 204 ha (General Census of Agriculture). The figures have increased slightly since 1988 when they were 214 ha (total area) and 171 ha (AA) respectively. The number of rice growers has increased continuously since the re-launching of French rice growing in the early 1980s, rising from 89 in 1979 to 179 in 1988 and 193 in 2000 (Table IV). In 2004, France had some 220 rice growers, mainly located in the Camargue. Of these, nearly three-quarters were in the Bouches-du-Rhône department and a quarter in the Gard; the distribution of rice growing areas displays very similar proportions in the two departments.

Table IV. Evolution of rice farms and farm labour in the Camargue

	1979	**1988**	**2000**
Number of farms	89	179	193
Total area	27 565	38 389	42 581
Average area	310	214	221
Usable agricultural area (AA) on rice farms	18 928	30 565	39 323
Average AA	213	171	204
Family population	263	543	672
family members working on the farm	143	297	347
Agricultural working population	ND	689	919
paid workers	ND	448	672
Share of paid workers in total working population	ND	65%	73%
Share of family workers in total working population	ND	35%	27%

Source: DRAF PACA, RGA, 1979,1988, 2000

3.1.2 Agricultural working population

The working population of rice farms totalled 919 workers in 2000, including 672 paid agricultural workers (73%). It is to be noted that rice growing is less and less a family occupation. In 1988, a good third (35%) of agricultural workers were family members and in 2000 the latter formed only 27% of the agricultural working population on rice farms in the Camargue. The share of paid labour, a fair proportion of which is seasonal, increases with the agricultural area. On the large farms (between 300 and 550 ha), 89% of working hours are performed by paid workers (Table V). In contrast, on small and medium-sized farms, paid working time is decreasing to the benefit of family labour, which is tending to increase. On farms with an area of 50 to 100 ha, family workers account for 65% of AWUs (Annual Work Unit) against 55% in 1988, while paid workers represent 34% of AWUs against 43% in 1988.

Table V : The working population in Camargue rice growing by farm size in %

	1988			2000		
Usable area	Total family AWUs	Total salaried AWUs	Total machine coop. AWUs	Total family AWUs	Total salaried AWUs	Total machine coop. AWUs
– 50 ha	77	23	-	81	16	3
50 – 100 ha	55	43	2	65	34	1
100 – 150 ha	39	60	1	58	38	3
150 – 300 ha	36	64	1	27	71	2
300 – 550 ha	19	81	1	10	89	1
550 ha –	10	90	-	21	79	-
Average distribution	34	65	1	26	73	1

3.1.3 Evolution of Camargue rice farms

The size of rice farms has increased as a whole since 1988. A concentration trend is observed with holdings larger than 150 ha forming 46% of rice farms in 2000 against 40% in 1988 (Table VI). These farms account for 79% of the usable AA against 74% in 1988. The results in 2000 were very similar to those of 1977, when rice growing was suffering a serious economic crisis, with the area under rice down to less than 8,000 ha; the bottom was hit in 1982 with only 4,200 ha under rice and when nearly half (47%) of rice farms had an AA greater than 150 ha. The figure was 46% in 2000 against 40% in 1988 when the re-launching of rice growing had enabled the return (or entry) of rice growing on small and medium-sized farms in the Camargue.

Table VI. Number of farms and %

	1979		1988		2000	
Usable area	Nb	%	Nb	%	Nb	%
– 50 ha	9	10.1	33	18.4	28	14.5
50 – 100 ha	17	19.1	47	26.3	47	24.4
100 – 150 ha	21	23.6	28	15.6	30	15.5
150 – 300 ha	21	23.6	40	22.3	47	24.4
300 – 550 ha	15	16.9	23	12.8	30	15.5
550 ha –	6	6.7	8	4.5	11	5.7
Total in Camargue	89	100	179	100	193	100

The dominance of large rice farms is also seen in the areas under rice (Table VII). Holdings with more than 150 ha account for more than 75% of the area under rice whereas the figure was only 68% in 1988 and 70% in 1977.

3.1.4 Evolution of the position of rice on Camargue farms

The evolution of the position of rice growing on farms shows a trend towards specialisation. On comparatively small farms (less than 100 ha) the share of rice in the AA has increased continuously over the past 20 years. On farms smaller than 50 ha, it increased from 54% in 1977 to 62% in 1988 and to 72% in 2000. On farms with an area of between 50 and 100 ha, it increased from 45% to 56% in 1988 and to 62% in 2000 (Table VII). The trend is also found on large farms with an AA of more than 300 ha. In contrast, a slight dip is noted in medium-sized farms (between 100 and 300 ha), where the area under rice is nonetheless greater than 50% of the AA.

Table VII.

		1979			1988			2000	
Usable area	Rice Surface (ha)	Rice Surface (%)	Share of rice in AA (%)	Rice Surface (ha)	Rice Surface (%)	Share of rice in AA (%)	Rice Surface (ha)	Rice Surface (%)	Share of rice in AA (%)
– 50 ha	158	2.2	54.1	657	4.5	66.3	610	3.1	72.3
50 – 100 ha	601	8.5	45	1979	13.6	55.8	2182	11.2	61.8
100 – 150 ha	1353	19.1	52.7	1959	13.5	58.6	2078	10.6	55.6
150 – 300 ha	1734	24.5	40.7	4563	31.3	55.2	5280	27.0	53.5
300 – 550 ha	1374	19.4	22.5	3827	26.3	42.8	5549	28.4	47.1
550 ha –	1854	26.2	42.5	1579	10.8	28.9	3850	19.7	40.3
40.3Total in Camargue	7074	100	37.4	14564	100	47.6	19549	100	49.7

The trend for large-scale rice growing can also be seen in the size of the areas under rice (Table VIII). In 2000, it can be seen that 80% of rice was grown in areas greater than 75 ha against 73% in 1988. Areas under rice smaller than 50 ha formed only 10% of the total area under rice in comparison with some 15% in 1998.

Table VIII.

	1979		1988		2000	
Usable area	Rice surface (ha)	Rice surface (%)	Rice surface (ha)	Rice surface (%)	Rice surface (ha)	Rice surface (%)
– 25 ha	236	3.34	547	3.76	541	2.77
25 – 50 ha	805	11.38	1518	10.42	1661	8.50
50 – 75 ha	832	11.76	1901	13.05	1720	8.8
75 – 150 ha	2581	36.49	3899	26.77	4713	24.11
150 ha –	2619	37.03	6698	45.99	10911	55.82
Total	7073	100	14563	100	19546	100

3.1.5 Agricultural occupancy of land in the Camargue

Cereal crops are dominant on rice farms. In 2000, they accounted for 70% of the AA (Table IX). The proportion has been comparatively stable for the past 20 years. Rice and durum wheat are the two most commonly grown grain crops. They are closely linked as 77% of rice farms perform a rice – durum wheat rotation, with rice as the crop that desalinates the land before the sowing of dry crops. Forage crops and permanent grazing land also form a fair proportion of the usable AA (20%). Industrial crops (oil plants) are decreasing strongly today after promising development in the 1980s and 1990s; this involved sunflower in particular, which remains the favourite among this type of crop. Vineyards are also tending to decrease on rice farms. Only 10% of farms grew grape vines in 2000 against 34% in 1977 and 13% in 1988. In contrast, the farms that have maintained vineyards have increased the area to an average of 42 ha per farm in comparison with 22 ha in 1988. Finally, fallows increased because of the CAP set aside land obligation. This formed 5% of the AA in 2000 against less than 2% in 1977 and 1988.

Table IX. Land use in the Camargue

	1979		1988		2000	
	Farms	Area (ha)	Farms	Area (ha)	Farms	Area (ha)
Cereals	89	12822	179	20884	193	27470
of which rice	89	7074	179	14563	193	19548
soft wheat	17	583	4	60	5	87
durum wheat	61	2765	117	5688	148	7321
barley	10	86	4	21	5	21
maize			17	360	13	351
sorghum	24	459	16	173	12	122
Industrial crops	18	231	67	1808	41	830
of which rapeseed	13	177	12	177	8	109
soy	2	20	10	144	5	65
sunflower	1	1	56	1464	32	656
Grape vines	31	1327	23	508	19	804
Forage	38	793	29	716	31	726
of which sown pasture	35	595	28	660	26	597
Land always under grass						
of which little grazing	30	2936	52	5447	58	7232
Vegetables	9	2597	30	4858	45	6357
Orchards	14	359	20	448	19	181
Fallow	7	53	12	289	5	200
	27	362	31	397	128	1832
Agricultural land used	91	18981	181	30596	193	39323

3.1.6 Livestock farming on Camargue rice farms

Livestock rearing operations are comparatively rare on rice farms (Table X). Horses are the most common animals, present on 23% of the farms. However, only 9% possess cattle. In contrast, those that do rear cattle have larger herds with 141 head per farm against 103 head in 1977 and 97 head in 1988. Among other types of livestock, only sheep are tending to remain but on only 4 rice farms against 7 in 1977. In contrast, goat and above all pig farming have completely disappeared from rice farms.

Table X

	1979		1988		2000	
Livestock	Farms	Head	Farms	Head	Farms	Head
Cattle	10	1027	16	1550	18	2533
of which cows	8	337	14	500	17	865

cattle less than 1 year old	7	182	12	262	18	525
male cattle aged 1 to 2 years	7	106	11	156	13	266
male cattle over 2 years old	8	167	14	357	15	463
Horses	23	536	50	525	44	541
of which breeding mares	15	264	29	242	27	190
Sheep	7	4603	5	2518	4	3463
Goats	1	6	3	19		
Pigs	2	4118	1	12	1	2

3.1.7 Rice production costs in the Camargue

These data are drawn from continuous monitoring of production costs by the Office Nationale Interprofessionnel des Céréales (ONIC) since 1995. Total production costs were evaluated for 2002 at € 1906 per ha (Table 9), of which a little more than half (€958) represented operating costs (variable costs) and € 948 spent on structural costs (fixed costs).

- Estimation of the cost of irrigation

Rice growing in the Camargue requires an average of 25,000 m^3 per ha per year. The cost of water for cropping requirements is significant on an average 100-ha farm. It forms 16% of production costs. Water management costs are broken down as follows:

— maintenance of networks and equipment: 5%
— payroll costs: 3%
— pumping and water rights: 8%.

- Estimation of the cost of drainage

Excess water, losses and leakage from rice growing are discharged by the drainage network. In this, water intake is downstream of each rice field and flow is then conveyed by the main drains that are generally discharged by pumping into the Rhône or directly into the sea.
The costs involved in the maintenance and functioning of the drainage equipment form 1% of production costs. Nevertheless, all activities and inhabitants participate on the equipment and operating costs of the network.

Excess water from farms is generally partially recovered for the requirements of the delta wetlands.
It is difficult to assess the quantity of fresh water required for good conservation of the natural environments in the Camargue. However, if all the hydraulic installations in the delta had to be maintained just for the conservation of wetlands, the cost of the management of these environments would be about €1.5 million per year.
However, the costs of this management have been borne to date by all the farming activities, and a large proportion (80%) is obviously funded by rice growers.

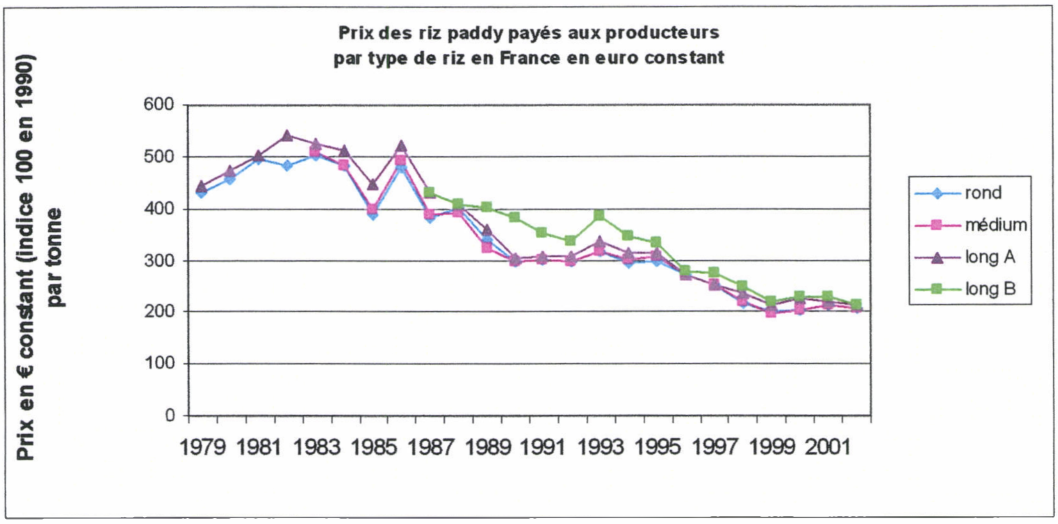
- Inputs

The relative shares of operating and fixed costs have varied little in time. Among operating costs, inputs (seed, fertiliser and pesticides) are the largest budget item, accounting for more than a quarter of total costs (TC). A comparative decrease in the cost of inputs is observed nonetheless thanks to a reduction in the cost of seed and pesticides. In contrast, the cost of fertiliser is steady at about 8.5% of

TC. Similarly, irrigation and drainage remains at between 8 and 9% of TC. The three largest fixed cost items are labour (paid and self-employed) at 15% of TC, land at 11.3% and depreciation at 11%.

- Movement of rice production costs in France

In terms of efficiency, the ONIC study reports a decrease in the cost per tonne of rice produced from €316 euros per tonne in 1998 to €301per tonne in 2002. The figure was €309 in 1996 and €323 in 1995. The best results for the period were in 1997 when the cost was €284 euros per tonne thanks to excellent yields (6,410 kg per ha in comparison with an average of 6,124 kg per ha during the period 1995-2002) and good mastery of the cost of inputs (€507 against an average €533 for the period 1995-2002). Although the costs per tonne of rice produced are fairly well mastered, farm incomes tend to decrease because of the fall in the intervention price and, indirectly, the price paid to growers. Thus the latter for long grain A fell from €443.53 per tonne in 1979 to €213.96 per tonne in 2002. This fall was made up for by compensatory aid from the European Union of €96.35 per ha in 1997, €192.70 per ha in 1998 and €289.05 per ha since 1999. However, this is only partial compensation for the decreases in producer prices and rice growers' incomes are falling.



- The economic balance of rice farms in the Camargue

Today rice growing in France is exposed to a real economic risk. According to a study by management centres in the Gard and Bouches-du-Rhône departments, the pre-tax profit of farms practising rice monoculture (€159 per ha) is smaller than that of farms producing rice and durum wheat (€185 per ha) or farms on which durum wheat is dominant (€167 per ha). There is thus a risk of seeing rice farms concentrate more on durum wheat rather than rice.

Table XI. Evolution of rice production costs in the Camargue

	1995	1996	1997	1998	2002
Yield in kg per ha	5.750	6.050	6.410	6.080	6.330
Operating costs	**958**	**983**	**915**	**975**	**958**
Seed	144	146	131	146	130
Fertiliser	162	167	147	151	163
Pesticides	238	265	229	246	199
Irrigation	135	137	127	139	151

Drainage	15	15	15	15	15
Drying	61	65	68	65	68
Power	41	42	41	36	53
	43	41	39	42	35
Work by third parties	79	71	89	108	121
Short term interest	40	34	29	27	23
Fixed costs	**899**	**890**	**909**	**950**	**948**
Paid labour	136	110	114	131	130
Self-employed labour	100	137	141	155	159
Depreciation of equipment	240	219	207	199	207
Long-term interest	28	27	26	25	38
Land	195	195	206	217	215
Taxes	40	37	52	59	52
Special taxes	7	7,5	8	7,5	7
Storage insurance	48	50	47	47	19
Overheads	105	107	108	109	120
Total cost per hectare	**1 858**	**1873**	**1824**	**1925**	**1906**
Cost per tonne in euros	**323**	**309**	**284**	**316**	**301**

Source: ONIC, 2004

2 – Taking into account the environmental quality of the Camargue

Since 1990, the rice growing profession has concentrated on the enhancement of product quality and the improvement of cultural techniques in order to reduce nuisance to the environment.
A first stage was reached when Camargue rice was awarded a PGI (Protected Geographical Origin). Conformity certification of 'Riz de Camargue' is obtained by the respect of specifications in which farmers must use a crop management sequence recommended by the Centre Française du Riz (CFR). Water management in rice fields, pesticide application and the quality of the grain harvested are defined by measures, with the growers' association performing controls and audits of sector operators. The territory covered by the PGI is also based on the certification of rice and covers most of the rice production zone in the Rhône delta. Today, 75% of the Camargue rice area is concerned by the label (15,000 ha).

Farmers' representatives wished to go further in 1998, in particular by proposing an agri-environmental approach in a Land Use Contract (*Contrat territorial d'exploitation*, CTE) entitled 'Rice and associated crops'.
The specification for its environmental component is aimed at:

- conserving a minimum area under rice,
- rotating crops,
- reducing nitrogen fertilisation,
- planned control of weeds and rice steam borer (pyralid).

Since 2000, the CTE has enabled the contractualisation of more than 5,000 ha of rice fields in the Bouches-du-Rhône part of the delta. PGI and CTE are thus procedures aimed at improving rice quality and also at reducing the negative impact of rice growing on the natural environments in the Camargue.

3 – The rice seed sector in France

Rice seed requirements in France total about 4,200 tonnes each year for the sowing of 19,000 ha (in 2004) at an average sowing density of 220 kg/ha. According to estimates, certified seed is used on

85% of the sown area, that is to say 3,500 tonnes sown on 16,000 ha. The remaining area (slightly less than 3,000 ha) is sown with 700 tonnes of farm seed.

Until recent years, 80% of the certified seed used was from Italy. Today, there is a strong trend to replace the Italian varieties by French varieties. Thus, in the 2004 season, certified seed of Italian origin totalled about 50% of the amount used, that is to say for sowing 8,000 ha. The remaining 8,000 ha was sown with certified seed produced by the French research sector.

Sud Céréales is the main rice seed supply company in France. It is reported to have sold nearly 2,300 tonnes of certified seed in 2004; of this, 1,700 tonnes was purchased by some 150 of the 220 rice growers in the Camargue region), 150 tonnes was sold to other sellers in France and some 500 tonnes was sold on the intracommunity market. Sud Céréales is thought to have 50% of the certified rice seed market in France. The rest of the market is supplied by French sellers (5 in the Camargue region).
There is also a 'micro-sector' for organic rice seed handling about 150 tonnes for an area of 500 to 700 ha sown by about 25 organic rice growers in France.

Table XII. The rice seed sector in France

	Ha	Tonnes
Seed required	19,000	4,200
Certified seed	16,000	3,500
Farm seed	3,000	700
Italian certified seed	8,000	1,750
French certified seed	8,000	1,750
Sud Céréales seed from France	7,500	1,700
French sellers of seed from France	500	150

Source: Sud Céréales

Sud Céréales integrates the entire seed chain: research, production and sales. Since 2001, research at Sud Céréales has been conducted in partnership with the Centre Français du Riz (CFR) and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) with Sud Céréales funding one of the two breeders based at the CFR. In exchange, Sud Céréales is though to have precedence in propagating the varieties resulting from this research and receive royalties for the certified seed sold.

In France, seed multiplication—controlled by Sud Céréales—is by a network of some 20 grower/propagators using about 400 ha. These growers must deliver their entire production to Sud Céréales and receive a multiplication bonus of 10% over and above the international price. In 2004, propagators received €222 per tonne (including a bonus of €22). The price for propagators for the 2005 season could be set at between €145 and €155 per tonne (including a bonus of €15). The price of seed rice for the 2004 season was €550 per tonne with discount of €10 per tonne for untreated seed (€15.20 per tonne for treatment), making the price of treated seed €555.20 per tonne (€55.52 per quintal), that is to say 2.78 times the price of rice grain.

The rice grain price in the 2005 season could be between €130 and €140 per tonne. The price of seed rice would be four times that of grain if the price is not reduced. It is thus to be feared that growers will sow a larger proportion of farm seed and this would result in difficulties for the entire seed sector from varietal research to the sale of certified seed.

Another aspect to be highlighted is the fear for the quality approach undertaken by growers through their association and the other players in the rice sector in France (Syndicat des Riziculteurs de France et Filière) since the 1990s, with *Certification de Conformité* obtained in 1998 and Protected Geographical Indication (PGI) obtained in 2000 for 'Riz de Camargue'. The production and processing of the PGI product must be conducted in the specified geographical area. Thus, all the production and processing stages of Camargue rice (except for packaging and sales) must be accomplished within the PGI area. This is why most of the companies mentioned above are Camargue concerns. One of the strong points of 'Riz de Camargue' is its traceability throughout the chain. This is imposed by the specification and includes the seed used. Among other things, the table below shows the areas that are certifiable and that correspond more or less with those mentioned above for the areas sown with certified seed. About 75% of growers and areas are under PGI.

Table XIII

Harvest	Certifiable area	Certifiable production in tonnes	Number of growers involved
1999	14,983 ha	89 238 t	180
2000	16,153 ha	91 719 t	172
2001	18,168 ha	100,606 t	185
2002	16,658 ha	92,082 t	179
2003	16,998 ha	84,627 t	175

3.4 – Market organisation

Downstream sector stakeholders are mainly in the same Camargue production zone. They include:

- establishments that store rice delivered from the field. There are 8 of these, all in the Camargue;
- professionals who perform the various rice processing operations (cleaning, threshing, milling, polishing, etc.). There are 6 of these, also all in the Camargue;
- packagers who pack rice before the wholesale or retail stages. There are 8 of these, half of whom are in the Camargue;
- traders who sell bulk white rice. There are 13 of these, of whom 6 are in the Camargue.

However, a fair number of these stakeholders may perform several functions. For example, a storage establishment may also be a rice processor or a processor may also perform packaging. In fact, there are 23 establishments (including one cooperative) in the sector and 17 of these are in the Camargue. This geographical proximity makes for good operation and numerous occasions for discussions and reflection on the organisation of the sector. This proximity was also a favourable factor in obtaining the Protected Geographical Indication (PGI) label in 2000. These 23 establishments have considerable economic weight. In 2002, they achieved sales of €378,150,000, of which €58,750,000 was drawn from their rice operations alone; they employed 995 persons on a full time basis and 171 of these worked on rice alone. The establishments based in the Camargue have sales of €167,200,000, with €55,600,000 from rice and 632 full-time jobs, including 165 devoted entirely to rice.

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