

Chapter 5

Soil Salinisation in the Grosseto Plain (Maremma, Italy): An Environmental and Socio-Economic Analysis of the Impact on the Agro-Ecosystem

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Abstract Soil salinisation jeopardises economy and landscape formed in Grosseto Plain during the last two centuries. Observed evidences show that soil salinisation is not due to climate change and rain reduction, but predominantly to the agricultural techniques of the local farms, which require large water supplies for irrigation. Water is drawn heavily from brackish water bodies too. In turn, in this coastal zone the excessive exploitation of groundwater increases the entry of salt water from the sea into the groundwater table. This research indicates alternative agricultural techniques fit to avoid soil salinisation and aimed at maintaining agricultural profitability as well as the landscape in the Grosseto Plain.

Keywords Agricultural desertification • Soil salinisation • Agro-ecosystem • Saline water irrigation • Agronomic management

5.1 Introduction

Soil salinisation is one of the main soil degradation processes in the Mediterranean area. At the same time, it is a promoter and a consequence of desertification, that is the progressive degradation of fertility in the surface layer of the soil and of the production capacity of arid, semiarid and dry sub-humid lands, which can be attributed to stresses due to climate and to the unsustainable pressure of human activity on the environment (UNEP 1994).

In the Grosseto Plain (central Italy), where agriculture is the main economic activity, the agro-ecosystem is the main environmental feature and the rural landscape is an important determinant of the economic and social welfare of its inhabitants.

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Soil salinisation is the soil degradation process of major impact since it affects soil fertility and crop production. The causes of salt accumulation in the soils of the Grosseto Plain are the use of saline water for irrigation and the rise of salts from groundwater to soil surface by capillary action; this process is mainly due to the intrusion of sea water into the groundwater table because of the overexploitation of water resources for irrigation and domestic uses. Increasing salt concentration in the Grosseto Plain soils is usually not considered a serious risk because the salt-leaching action of the autumn–winter rainfalls is thought to be sufficient to prevent salt accumulation in the soil. However, the continuous decrease of cultivated hectares because of soil salinity, the continuous loss of irrigation water resources because of groundwater salinisation and the future climatic scenarios call for a review of this belief. Indeed, agronomic management of the salinisation process via proper cultivation techniques for the control of soil salt accumulation is very important for sustainability of this agro-ecosystem.

The aims of this paper are to describe the agricultural scenario and economic and environmental importance of the Grosseto Plain agro-ecosystem, and to present the research carried out within the WADI Project in regard to salinisation of cultivated land in the Grosseto Plain induced by irrigation practices.

5.2 The Grosseto Plain: A Recent Landscape with an Age-Old History

A broad plain dotted with houses, crossed by roads and furrowed by channels that define a myriad of cultivated fields (in most cases irrigated), with small patches of marshland preserved because of their historical and environmental value: this is the current image of the Grosseto Plain, the most intensely cultivated and anthropised part of Maremma, a coastal alluvial plain of about 390 km² south of the city of Grosseto between the Bruna River and the Ombrone River, mainly surrounded by low woody hills and separated from the sea by a band of coastal vegetation. Today's Grosseto Plain is a recent, evolving landscape, the result of exceptional human activity. Centuries of reclamation work have transformed and managed the water and soil, the basic elements that constitute and define the Maremma landscape (Caldelli 2003). Through the control and management of water-courses (hydraulic reclamation) and the drainage and permanent increase of soil depth (soil reclamation), man has continuously acted on the water and soil of Maremma to transform the landscape and improve the living conditions of its inhabitants.

Originally (6000 BC) the Grosseto Plain was an inland lagoon (Prile Lake) separated from the sea by a set of dunes where the present coastline is located. The dunes were created by the concomitant action of sea-erosion and soil-transport by rivers, the same water-courses that caused the progressive filling up of the lagoon and the formation of the alluvial plain by deposition of sediments.

The first human settlements in the territory surrounding the Prile Lake belong to the Etruscan-Roman period, when the economy of the populations was based on

fishing, agriculture and trade with neighbouring towns of the Tyrrhenian coast. In the Roman age, the water-courses were maintained to allow irrigation for the flourishing agriculture and to ensure their navigability. The end of the Roman Empire and the subsequent barbarian invasions put an end to the damming and cleaning of the water-courses, which resulted in recurrent overflowing of the rivers and expansion of marshland in the plain.

The first attempts of land reclamation were carried out by monks around AD 1000. But they resulted in vain because of the recurrent wars, which caused the abandonment of agriculture, the increase of the marshlands and the spread of malaria. The first real works of reclamation in Maremma were carried out under the Medici dynasty rule. They consisted in the excavation of ditches and channels to remove the water and drain the pools of the marshland. However, the incomplete reclamation (removal of water without filling the empty spaces caused by the drainage) and the uncertain economic policy of the Medici in Maremma (co-existence of agriculture, fishing and sheep-raising) resulted in a 'disorderly' landscape, where the fields cultivated for subsistence farming were under the permanent risk of flooding and of unsustainable hygienic-sanitary conditions.

In the eighteenth century, after the Medici period, Maremma was under the control of the Habsburg-Lothringen dynasty (1737–1860), which established innovative socio-economic policies (abolition of some feudal privileges, the centrality of agriculture in the economic development of Maremma, encouragement of farming) and began regular land reclamation based on the 'colmata' system, that is the artificial aggradation by deposition of river-borne sediments. In the period 1829–1832, two channels to transport the muddy water of the Ombrone River to the marshland were excavated; Leopold II enacted specific laws on land reclamation and many works were conducted for the control of rivers and to counter flooding of the plain.

In 1859, Maremma was annexed to the Kingdom of Italy and, for the next 60 years, reclamation followed the Habsburg-Lothringen dynasty pattern. Nevertheless, sediment filling up of the adductor channels of the water due to the 'colmata', the poor sanitary conditions of the area and the uncertain political climate of the time (dominated by revolutionary movements and internal wars) interfered with the reclamation of the plain and the work was often abandoned. At the end of World War I, the Maremma plain was still a very hostile environment for man and his activities. The variable topography (many areas were under permanent risk of submersion because of their low slope and/or elevation above sea level), the irregular hydrography (not all the ditches and channels of the drainage network had the same direction towards the sea) and the endemic presence of malaria made the plain a sparsely populated territory in which itinerant sheep-raising was carried out alongside subsistence agriculture based on wheat monoculture by seasonal and temporary labourers.

An important step towards the transformation of the Maremma landscape and socioeconomic development of the area was the establishment of the 'Consorzio di Bonifica' (Land Reclamation Consortium) of Grosseto in 1930, when several prominent landowners joined to manage the reclamation works of the plain. The aims of the Consortium, whose territorial bounds largely coincided with the present Grosseto Plain, were: to obtain and maintain thicknesses of soil free from stagnant

water in all fields of the plain; to develop highly productive and profitable agriculture; to favour permanent settlement of the rural population in Maremma. To achieve its objectives, the Consortium built channels to convey the water coming from the hills into the main water-courses and positioned four water-pumps to accelerate the 'colmata' process and remove the drainage waters. Instead of mass employment of seasonal day-labourers, the 'mezzadria' (sharecropping) system was adopted as the new socioeconomic pattern for the rural development of Maremma. The first agricultural machines and new cultivation techniques were introduced in the large landed estate (latifundium) farms: fallow and pasturage were gradually abandoned and the cereal yields increased thanks to the adoption of biennial or quadrennial crop rotations. As the reclamation process proceeded, new infrastructures (roads, aqueducts, irrigation channels) were created to support the economic development of Maremma and repopulation of the countryside.

The period of agricultural development of the plain and evolution of the Maremma landscape due to the initiative of the landowners continued till World War II, and the most evident signs of the socioeconomic transformation of the Grosseto Plain were the establishment of many new farms and the arrival of many rural families, also from other regions of Italy.

After World War II, the newborn Italian Republic declared Maremma a rural area of national interest for development of the country, and management of the transformation and development of the area was taken over by the Italian Government. Under public administration, the territorial, economic and social transformation of the Maremma plain greatly accelerated: the total land reclamation was completed, malaria was vanquished thanks to the massive use of pesticides, and the 'Riforma agraria' (rural property Act) was enacted in 1950.

The Land Reform was the fundamental legislative act that determined the present socioeconomic structure of the Grosseto Plain (Lucetti 2003). Its basic aim was the coincidence of land ownership and rural work: the farmer and the landowner had to be the same person. Before 1950, Maremma was organised in large estates (72% had more than 100 ha and estates larger than 1,000 ha occupied 45% of the total cultivated land) managed by rich landowners, and extensive agriculture and the 'mezzadria' system defined the agricultural scenario. Through the Land Reform, many people (more than 15,000) became landowners and the main consequence, other than the (virtual) disappearance of latifundia and mezzadria, was the birth of a new socioeconomic class consisting of farmers who carried out their own agricultural production on their own farm. Moreover, new houses, schools, churches, food shops and roads were built to support the work and daily life of the land assignees and their families; agriculture became increasingly intensive, transhumance disappeared completely and new crops, such as sugar beet, sunflower and vegetables, joined the traditional cereal crops. The rural property Act was the logical conclusion of the centuries-old reclamation process in Maremma, and its effects on the landscape and socioeconomic structure of the plain are well visible today.

The Grosseto Plain is now a highly impacted landscape, a large agro-ecosystem where the main economic activities are agriculture and tourism (also combined in recent decades). The agricultural activity is carried out in a dense network of highly productive farms spread over a total cultivated area of about 29,000 ha.

Agriculture also allows a flourishing and widespread activity of in-farm tourism (agritourism) and the production of forage crops supports an important cattle breeding industry. Therefore, the agro-ecosystem is the main environmental feature of the Grosseto Plain, and the rural landscape is important in determining the economic and social welfare of its inhabitants.

The Grosseto Plain is a dynamic, always evolving landscape, and its sustainability requires a balance between human activities and uses of environmental resources. For a long time, the continuous work of reclamation and the 'good' management of natural resources resulted in environmental sustainability of the agro-ecosystem. However, the economic and environmental balance of the rural landscape has become endangered in the last 10–15 years because of mismanagement of the resources (above all water and soil). The most evident and dangerous threat to sustainability of the agricultural activity in Maremma is the salinisation of groundwaters and cultivated fields.

The problems due to water and soil salinisation in the Grosseto Plain have been known for a long time: for example, the wells drilled near the coast by the 'Consorzio di Bonifica' of Grosseto around 1935 to provide fresh water for the population and for agricultural activities proved unsuitable for humans and animals because of the high salt content of the water. The first important studies of soil salinisation were carried out by the University of Florence in the second half of the past century. At the time, however, salinisation processes were limited to circumscribed areas near the coast, while soil and water salinisation have become increasingly dangerous and widespread in the last decade: each year, the distance from the coast of wells unusable because of their water salinity increases, and there is an increase every new crop season of the number of hectares no longer suitable for intensive, specialised and highly productive agriculture on account of the rising soil salt content.

The increased salt concentration in the cultivated fields of Maremma is a very dangerous soil degradation process because it affects overall soil fertility (physical, chemical, biological) and thus has a harmful effect on the productivity and economic sustainability of agriculture in the Grosseto Plain. Moreover, total reclamation of salt affected soils is not generally possible, and the agronomic control of salinity is very complicated because of the many aspects (soil, climate, hydrology, irrigation, cultivation techniques) involved in the soil salinisation process.

Knowledge of the territory and the mechanisms that determine soil salinisation are essential to define proper agronomic management of soils threatened by salinity and to preserve their fertility, so that agriculture will continue to be an opportunity for socioeconomic development of the Grosseto Plain and the agro-ecosystem will remain the major feature of its landscape.

5.3 The Agricultural Structure of the Grosseto Plain

The Grosseto Plain is an important agro-ecosystem of the Mediterranean area, where agriculture is carried out on more than 2,000 farms covering about 29,000 ha. Most of the farms are small (average farm 14 ha) and almost all of the agricultural

labour is carried out by the farmers and their families (Camera di Commercio Grosseto 2006, 2007).

Almost all the agricultural production of the Grosseto Plain is due to the cultivation of herbaceous crops, and only 9% of the total agricultural land is devoted to woody crops (Fig. 5.1). Because of the climatic features of the Grosseto Plain, characterised by a coastal Mediterranean climate with a strong, permanent hydro-climatic deficit during the spring–summer cultivation season (Regione Toscana 1984), the agricultural production of the spring–summer months requires irrigation. In 2000, about 35% of the cultivated area of the Grosseto Plain was under irrigation, and the most important irrigated crop (in terms of hectares) was tomato, followed by forage crops, vegetables and cereals (Fig. 5.2). Although livestock breeding in the Grosseto Plain has decreased in recent years, the production of forage (mainly alfalfa and maize for silage) is important for the many cattle farms in the Province of Grosseto. Another important aspect of the agricultural activity of the Grosseto Plain is the continuous increase of agritourism activities on the farms of the area (Regione Toscana 2007).

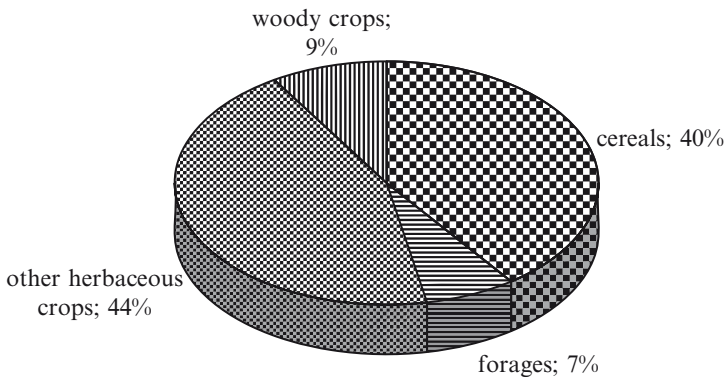


Fig. 5.1 Percentage division of the 'total cultivated land' of the Grosseto Plain agro-ecosystem

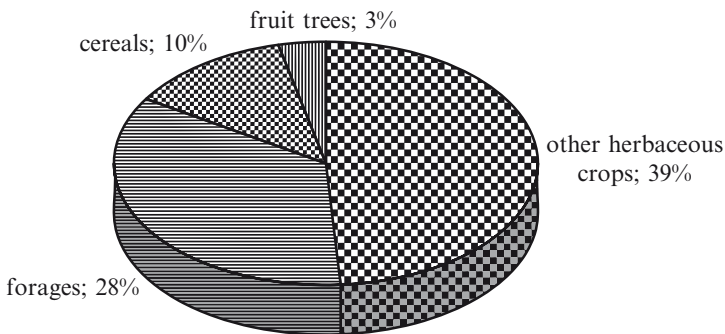


Fig. 5.2 Percentage division of the 'irrigated land' of the Grosseto Plain agro-ecosystem

In summary, in the Grosseto Plain the agricultural activity is carried out by a network of small farms, where most of the labour is carried out by the farmers and their families; the massive input in terms of labour, mechanisation, fertilisers and irrigation results in high productivity (crop yields), and agriculture provides the main or only kind of income for many people. Moreover, the number of tourists coming to Maremma because of the environmental quality of its agro-ecosystem has increased yearly in the last decade, and the rural landscape appears to be the most important product of Grosseto Plain agriculture within the context of the environmental and economic sustainability of the Maremma territorial system.

5.4 Salinity Hazard in the Grosseto Plain

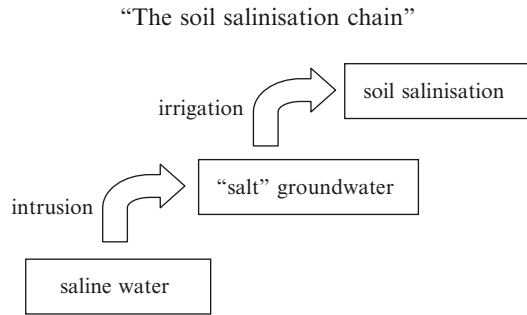
Soil salinisation is one of the main soil degradation processes in the Grosseto Plain and in the irrigated areas of the Mediterranean Basin: when considered in relation to persistence and permanence, the sustainability of irrigated agriculture is limited mainly by salinity and salinisation of the irrigated soils. All irrigation water contains soluble salts, and when the irrigation water is used, the water (which acts as a solvent) is largely removed from the soil or the plant by evapotranspiration, while the salt (the solute) remains in the soil. Thus, salt accumulation occurs after repeated applications and it is only a matter of time until a salinity regime is established, unless measures are taken to prevent it.

Problems due to soil salinity in the Grosseto Plain are well known. Several studies have demonstrated severe salinisation of the soils at several sites in the plain, especially in clayey areas with poor drainage (Breteler 1983; Zanchi and Cecchi 1995; Falciai 1996). Until 10–15 years ago, saline soils were limited to areas near the coast and water bodies (Sevink et al. 1986). The main mechanism of soil salinisation was identified as the entry of sea water along water-courses and reclamation channels during sea storms, and the consequence was the salinisation of soils because of the diffusion of saline water (Ungaro 1995; Pranzini 1996).

In the last decade, however, another soil salinisation process has become increasingly important and diffuse. Because of the overexploitation of water resources for human needs (agricultural, industrial and domestic uses), the natural equilibrium between fresh and saline groundwater has been disrupted, with the intrusion (and diffusion) of salt water from the sea into the groundwater table, the main source of water for irrigation (Beemster 1987). The consequence is salinisation of the irrigated soils (Fig. 5.3).

In the Grosseto Plain agro-ecosystem, many important crops (maize, tomato, vegetables, soybean, watermelon and alfalfa) are cultivated during the dry spring–summer season. The water deficit during the irrigation season is higher than 400 mm and more than 70% of the irrigation water is drawn from the groundwater table by hundreds of wells scattered across the plain. Therefore, we can understand the potential impact of such severe, rapid and widespread soil degradation on the economic and environmental context of the Grosseto Plain.

Fig. 5.3 Soil salinisation in the Grosseto plain: movement of salt from sea water to groundwater to soil



Another important aspect to be considered in evaluating the potential risk of soil salinisation is climate (van der Molen 1984). Saline soils are formed where the amount of salt that accumulates is greater than the amount removed. Since the migration of salts in soils occurs mainly through salt solutions, the main condition of salt accumulation in soil is the preponderance of evaporation over drainage. As a consequence, the processes of salt accumulation are governed first and foremost by the water balance of each particular area. Both the water balance of the area and the ratio of evaporation to drainage depend on climatic conditions.

The present Mediterranean climate is characterised by hot dry summers and mild wet winters. The region frequently has years of scant rainfall, and many areas are afflicted by severe drought. The alternation of a wet and dry season results in two critical periods related to the potential risk of soil salinisation: the first is the autumn–spring period when the often abundant rainfall may cause water stagnation; the second is the summer period because of the high evapotranspiration demand that causes salts to rise from the groundwater to the soil surface (Monteleone 2006).

Climatic analyses of the Mediterranean area show that the central and southern countries of the region are not at risk of water stagnation during the wet season; however, rainfall-induced leaching of the salts brought to the soil by irrigation is almost negligible. Moreover, scenarios developed with the most recent General Circulation Models for assessment of the hydrological impacts of climate changes predict that rainfall will decrease over much of the Mediterranean by the year 2050, especially in the southern parts where it could diminish by up to 25% with respect to the mean values of the period 1961–1990; the decreased precipitation should be accompanied by a rise in temperature of between 1°C and 3°C (De Wrachien et al. 2002a, b). Reduced precipitation will have a major impact on irrigation demands and the potential leaching action of rain (De Wrachien and Ragab 2003; Döll 2002; Seckler et al. 1997).

The climatic risk of soil salinisation in the Grosseto Plain has been investigated by an analysis of the climatological data for a 50-year period (1956–2005) at the meteorological station of Grosseto (Zanchi and Cecchi 2008). Three climatological parameters were considered: evapotranspiration, rainfall and the Climatic Water Balance (CWB), that is the difference over a defined length of time between cumulative rainfall and evapotranspiration requirements; CWB summarises the relative

importance of rainfall and evapotranspiration for the assessment of the climatic risk of soil salinisation (Fig. 5.4). The most important result of the climatological analysis was the persistent and progressive contraction of the Climatic Water Balance of the Grosseto area. The spring and summer seasons were characterised by a permanent lack of water surplus, and the arid period was prolonged to the autumnal months, with an average CWB around zero. The CWB of the winter season was positive on average.

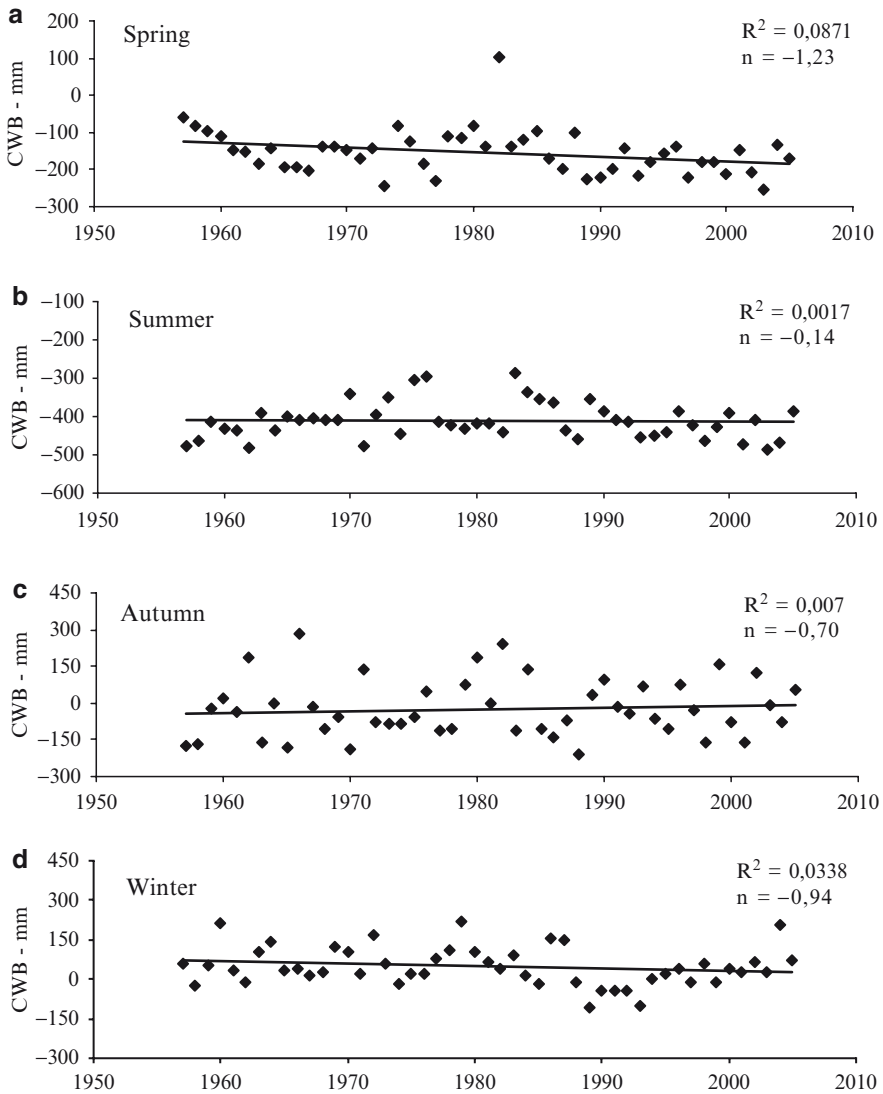


Fig. 5.4 Linear regression of the seasonal Climatic Water Balance (CWB, mm) during the 50-year period 1956–2005 at the meteorological station of Grosseto

(there was a surplus of rainfall for salt leaching) but not in every year; above all, it showed a trend towards values close to zero, indicating the risk of a chronic water deficit extended also to the winter months. Such a trend could reduce the autumn–winter rainfall-induced leaching of the salt accumulated in the soil due to irrigation during the spring–summer cultivation season. In the long run, this set of climatic conditions could prejudice the sustainability of irrigated farming systems in the Grosseto Plain.

5.5 Soil Salinisation and Agronomic Management of the Irrigated Land of Maremma

In recent years, the Grosseto Plain agro-ecosystem has experienced secondary salinisation of the irrigated soils due to the use of poor-quality irrigation water. The main consequence of this soil degradation process is reduced soil fertility, and from year to year the signs of ‘suffering’ by the agro-ecosystem are increasingly evident from both the economic and environmental point of view. In the decade 1990–2000, about 1,880 ha could no longer be irrigated because of the salinity of the water and a large number of wells became useless for irrigation purposes (ISTAT 2000). In the last 9 years (2000–2008), very remunerative crops such as onion became less important because they are saline-sensitive, while salt-tolerant crops (tomato and squash) spread on the irrigated land of Maremma (Regione Toscana 2008).

As a rule, total reclamation of salt-affected soils is not possible because supplies of good-quality water are not sufficient. The alternative for continued crop production appears to be the development of specialised management practices that lessen the damaging effects of salt and maintain as high a production level as feasible.

In irrigated areas affected by secondary soil salinisation, the agricultural limitations due to salinity become complicated because of manifold and complex soil–water interactions which depend on soil texture, soil structure, cultivation techniques, irrigation methods, water quality and water dynamics. In addition, the quality of irrigation water is expected to decrease because of strong competition for different uses of the water resources, and scenarios developed to assess the hydrological impact of expected climate changes, predict a major impact on irrigation water demand and the potential leaching action of climate over much of the Mediterranean (Alcamo et al. 2000). Therefore, soil salinisation of the irrigated land of the Grosseto Plain is predicted to get worse and the sustainability of agriculture activities will be compromised unless proper agronomic measures are taken to prevent it.

At present, the irrigated farms of the Grosseto Plain carry out highly specialised, intensive agriculture, and their farming systems are too rigid and inflexible for a timely response to the severe, rapid and widespread soil degradation induced by the use of saline irrigation water. As a consequence, in comparison with the secondary soil salinisation scenario, the farmers follow two main strategies: either they accept lower crop yields and continue with saline water irrigation or they change crop and cultivate more salt-tolerant plants and continue with saline water irrigation.

However, the end result of this behaviour is ‘agricultural desertification’: from irrigation season to irrigation season, the farmers promote salinisation of the soil, and it is only a matter of time before the soil salt content reaches a level incompatible with agriculture.

To avoid soil salinisation of the irrigated fields in the Grosseto Plain, the irrigation strategy must introduce the lowest possible amount of salt into the soil. The starting points are: to know the salt content of the irrigation water; on the basis of the specific soil characteristics, to carry out crop rotations that reduce the amount of irrigation water applied to the soil during the crop season; above all, to ensure sufficient salt leaching during the rainy season (rotation of irrigated and non-irrigated crops, autumn–winter and spring–summer crops, leafy and grain crops, etc.).

For continued crop production, the irrigated farms of the Grosseto Plain require agronomic management practices involving the farming systems as a whole rather than a focusing on single crops and/or single cultivation techniques.

Soil is one of humanity’s most precious assets
 It allows plants, animals and man to live on the earth’s surface
 Soil is a limited resource which is easily destroyed
 Farmers and foresters must apply methods that preserve the quality of the soil
 – European Soil Charter, Council of Europe, 1972

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