CHAPTER 7

RECONCILING PRODUCTION AND MANAGEMENT OF SCARCE RESOURCES*

Water, soil and energy are the lifeblood of the agricultural production process. The Mediterranean area, a place of settlement for peoples in transition from hunting to agriculture, clearly underlines human investment in the development of these resources. Hydraulic works from the depths of antiquity, the utilisation of the Nile alluviums and the early use of animal traction bear witness to this ancient search for ways of feeding people and ensuring social harmony.

However, the unprecedented changes sweeping through the Mediterranean (demographic growth, coastal settlement, urbanisation, etc.) and, more generally, of the planet (degradation of the climate, increasing scarcity of energy resources) now call into question the already fragile "soil-water-energy" balance, to the point where the portents for the future look rather bleak. With fossil energy becoming scarce and expensive, how can the agricultural sector and rural areas be developed without at the same time further degrading the soil and water?

On the horns of climatic change and energy shortages

Against a background of environmental urgency, recalled in the last IPCC Report *Climate Change 2007*, but also the looming energy shortage, the Mediterranean is facing a twin danger since its climate and energy supply are both under threat. Neither agriculture, rural development nor food consumption will be spared this gloomy outlook. Agriculture will suffer directly from the rise in energy prices. The most remote rural areas, especially in the South, will be further marginalised by the rising cost of transport. Agriculture cannot be transformed as easily if the energy supply worsens. Conversely, this context will force the Mediterranean countries to make a wholehearted commitment to set their agriculture and rural development on the path to a new green economy of energy saving and promotion of renewable energy sources.

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Clean energy, a major challenge

Renewable energy can undoubtedly solve the twin problem of future scarcity and environmental degradation. In 2007, the European Council put forward the need to base 20% of energy consumption on renewable sources by 2020, but almost all countries are falling behind in achieving this target, with the exception of Germany and Denmark.

Table 1 - Cost of renewable energy

Renewable energy	Average cost €/KWh
Photovoltaic solar energy	0.15-0.55
Thermal solar energy	Depends on type of installation
Wind power	0.03-0.13
Geothermal energy	0.07-0.08
Hydraulic power	0.05-0.11
Biomass	0.05-0.08

Source: Revue Arpa (2006); Nomisma Energia (2007).

Up to now, renewable energy has not been fully competitive in economic terms. It may become competitive when its environmental and social advantages are matched by the economic benefits or when the negative external impact of other energy sources (greenhouse gases - GHG - in particular) are included in their cost. For the time being, given the production costs from which they suffer, several governments have introduced incentives (financing facilities, subsidies and tax reliefs) to allow a certain return on investment at household, local authority and company level. Of course, this is not without its problems for States which lack the budgetary resources, especially some South and East Mediterranean Countries (SEMC). While increasing renewable energy production depends on support policies, it is above all linked to improving the efficiency of production systems. As this type of strategy, *a priori*, risks isolating the countries which produce fossil fuels, pilot projects initiated by Medrec (the Mediterranean Renewable Energy Centre), formed in Tunis in 2004 under the Medrep initiative (Mediterranean Renewable Energy Programme), and to which major oil producers such as Algeria, Libya, Egypt, Tunisia and Morocco belong, seek to base electricity supplies to isolated rural populations, tourist areas and irrigated zones primarily on renewable sources.

The potential for development of solar, wind and hydro-electric energy in the Mediterranean is considerable. Due to the high level of sunshine, photovoltaic panels and solar panels offer obvious possibilities, and would be way of alleviating the low level of electrification of rural areas. With a low environmental impact and requiring little maintenance, they nevertheless have a still very limited conversion and storage capacity. Studies are under way, however, to improve the efficiency of the cells and control the costs of equipment.

Thanks to its constant technological development, wind power is the cheapest renewable energy. According to the International Energy Agency (IEA) in 2004, its costs had fallen by 30 to 50% compared with the 1990s, which would go some way to explaining its advance. According to studies under the Euwinet project, it has been growing in Europe by some 35%, with 75% of this energy being produced by countries of the European Community. Spain is by far the most committed to this type of production, and among the SEMC, Morocco, Tunisia and Egypt also have areas of major development. Meanwhile, hydro-electric power is one of the most widespread natural energy sources in the Mediterranean Basin, with a real potential for development in countries which have plenty of watercourses. The power stations are often old, but can still be upgraded from the point of view of output and environmental impact. The lack of sites suitable for dams nevertheless limits the development of this energy. Since 1990, Turkey has been an exception with the GAP (*Güneydoğu Anadolu Projesi*, project which is designed to allow socio-economic development in South-East Anatolia). With 22 dams on the Tigris and Euphrates rivers, the country should double its electricity output. Lebanon also has clear room for manoeuvre since work on dam building has been limited up to now, despite the presence of numerous sites in this highly mountainous country.

Pluses and minuses of biofuels

Biofuels are increasingly presented as a panacea in the face of the energy shortage and climatic deterioration. Yet the idea is not really new, since Nikolaus Otto, inventor of the internal combustion engine, had designed it to run on ethanol, while Rudolf Diesel ran his internal combustion engines on groundnut oil.

Bio-ethanol is the most commonly manufactured. It is obtained from fermentation of agricultural products rich in sugar and starch, such as sugar cane, sugar beet, sweet sorghum, durum wheat, soft wheat, barley, maize, certain types of fruit, potatoes and grapes. The product is now widely used for vehicles in Brazil, a country which, in the new energy paradigm, is seeking to play a major role on the international scene relying on its land resources to supply it. As a mixture or even in its ether form (ETBE), it may be used pure or in very high concentrations but then needs a specific adaptation of the vehicle. It will generally be used, therefore, at lower contents between 5 and 10%.

Biodiesel is obtained by extracting vegetable oils from rape seed, soya or sunflowers. Compared with normal diesel, it reduces carbon dioxide emissions by 78% and, because it does not contain sulphur, has the advantage of not releasing any oxides of sulphur. Its only disadvantage is the considerable production of nitrogen oxide which could possibly be eliminated by new technology. The Eurobiodiesel project, financed by the EU, has shown that biodiesel can be used without any problems as a fuel for tractors, buses and cars.

Biogas is by far the least produced. Primarily manufactured in Sweden, it can be used as a fuel in thermo-electric power stations or in means of transport. By methanic fermentation of a tonne of biomass (organic animal matter or sugar-rich vegetable matter), it is possible (depending on the quality and nature of the organic matter) to obtain 70 to 150 m^3 of biogas (mainly bio-methane) which can produce up to 190 KWh of electricity.

Lagging far behind Brazil and the United States which are the largest producers of bio-ethanol in the world (some third of world production each), in 2005 the EU contributed some 10% of world production of bio-ethanol (or about 800,000 tonnes). Europe, however, is the largest world producer of biodiesel (75%), production of which is also rising in many regions of the world. The SEMC have not embarked on this energy substitution policy. Agriculture destined for biofuels can be adapted to the northern shore, if it takes account of the impact on the environment and forestry and does not neglect the food aspect. It cannot be applied in countries which already suffer from problems of desertification, land deficit and water poverty or shortage.

The European countries are increasingly promoting the benefit of biofuels to limit greenhouse gas emissions and to minimise energy dependence. In February 2006, the European Commission adopted a strategy which envisages a series of market-oriented measures in the legislative and research fields, designed to encourage production of biofuels from agricultural raw materials. According to the Commission, the increased use of biofuels would have many advantages, in particular reduced dependence of Europe on fossil fuel imports, limitation of greenhouse gas emissions, new outlets for farmers, and new economic opportunities for certain developing countries (European Commission, 2006).

A priori, the production of biofuels can limit GHG. The CO_2 released by their combustion corresponds to that which has been captured from the atmosphere by photosynthesis. However, to this neutral carbon balance must be added the "field-to-wheel" emissions related to the use of fertilisers, transport and transformation of products.[1] The biofuel manufacturing process itself can be highly energy consuming, as the manufacture of fertilisers, irrigation and transformation absorb not inconsiderable quantities. Estimates of energy savings and GHG are very varied. It is known, however, that ethanol made from Brazilian sugar cane is more beneficial in terms of GHG than American ethanol made from American maize. The future of biofuels probably depends, at least in part, on the advantages shown by these estimates.

Other problems have been suggested. Environmentalist associations often point to the deforestation which precedes the growing of biofuel crops in the major biofuel producers (Brazil, Indonesia), as well as the huge needs for irrigation required by such crops. Although other factors play a part (especially recurrent drought, population growth, suppression of export subsidies) there is equally no doubt that turning land to non-food production has contributed to the recent rise in agricultural commodity prices. Experts recently observed that "the current push to expand the use of biofuels is creating unsustainable tensions that will disrupt markets" (Doornbosch and Steenblik, 2007). In this regard, second generation biofuels, based on so-called "lignocellulose" resources (i.e. structural tissues of vegetable organs) seem to offer evident guarantees since they are crop residues (straw, grass) or forestry output. But these branches have not yet reached the industrial stage.

1 - According to Paul Crutzen (Max-Planck Chemical Institute, Mainz, Germany), Nobel Laureate for Chemistry in 1995, nitrogenous fertilisers would be converted in the soil into nitrogen protoxides (N_2O) in larger quantities than the 1% adopted by the IPCC. Given the high propensity of this gas to contribute to the greenhouse effect, it would considerably add to GHG in intensive production of biofuels. Notably, he published an article on this subject in the journal *Atmospheric Chemistry and Physics Discussions.*

Second generation biofuels

There has been much research into the transformation of vegetable lignin and cellulose (straw, wood) into alcohol or gas. The transformation technologies (enzymatic, e.g. enzymes of the bacteria from termite stomachs, or thermochemistry, combustion, gasification, pyrolysis) are rather complex, hence the delay in their industrial application.

Among second generation biofuels, micro-algae offer the most interesting prospects, both in terms of energy yields and the saving in land. Micro-algae have to be grown with a CO_2 concentration of about 13% the source of which may vary widely (coupling with a coal-fired thermal power station or an alcohol fermentation unit, for example). The overall carbon balance and the sustainable character of the chain thus depends on the source of CO_2 used. Coupling the cellulose ethanol chain with the micro-algae chain thus has a future in terms of sustainable development.

Farmers could have an interest in producing certain plants such as miscanthus. With a very good yield in dry matter which can be transformed into biofuel, this perennial plant is also economical in nitrogen and water and needs little treatment because it has few natural enemies.

While the development of the first generation chains is a response for Europe and its farmers, it might not necessarily be the best understood approach in the South Mediterranean, in particular in the oil-producing countries. This strategy may, indeed, be seen as a way of escaping the energy domination of certain Arab countries while imposing a rise in the price of cereals of which they are often big importers. The prospect of disputes forces the countries of the northern shore and, more broadly, Europe, to accompany these initiatives with information aimed at the South. More probably needs to be done. As with other resources, water and soil especially, Mediterranean cooperation is necessary to escape the old “energy paradigm”.

Adapting agricultural practices

The climatic changes and unprecedented trends in energy supply mean that agriculture is not immune to the need to change its practices. In France, the challenge is considerable, since 18% of GHG are produced by agricultural activity.[2]

To prevent excessive release of carbon, it can be better stored in the soil by not leaving land fallow, correctly ploughing in crop residues, practising tillage pass, converting agricultural land into permanent pasture or by grassing spaces between rows of fruit trees or vines. Conversion is not always necessarily a winning solution. While meadows are desirable because of their better carbon retention, their growth means that the number of animals using them increases, and animals release large amounts of methane. The type of pasture also has an impact on GHG, and the trade-off is not always simple from this point of view. A permanent meadow gives a better GHG balance than a temporary and intensive one which demands more fertiliser. However, an animal will give off less methane if its food is rich, which is more likely with intensive pasture. The research must therefore take into account the entire animal-pasture system, analysed in terms of GHG and energy expenditure.

2 - Inter-ministerial mission on the greenhouse effect.

In the particular case of water, micro-irrigation optimises water consumption and allows substantial energy gains because it only needs low pressure (1 to 2 bar). With variable speed lift pumps instead of constant speed pumps, additional energy savings of around 20% can be envisaged. Far from being anodyne, this type of saving should be promoted in the Mediterranean, because of the high cost of pumping in the majority of irrigated systems there (in Morocco, for example, it accounts for 60% of the total cost of the water).

Food consumption cannot be left out of the equation. If it becomes widespread, the shift towards more beef and milk in food intake can be catastrophic from the point of view of GHG emissions and energy expenditure. While agricultural activity cannot be impugned since its job is to feed people, the western food model which is calorie-intensive and generates large amounts of GHG can, nevertheless, be called into question. The Mediterranean food model, with less animal protein, could be a desirable response in promoting in the new energy and environmental paradigm.

Saving water: a vital challenge

In a Mediterranean region characterised by low rainfall, at least on the eastern and southern shores, the volume and quality of water are under threat. Many coastal countries suffer from water poverty and signs of growing pressure abound in the Mediterranean. The search for a balance between demand and availability, through general short and long-term strategies, is undoubtedly the most important challenge in the case of water resources. Forecasts suggest that, by 2020, the population will increase and that irrigated areas will continue to spread. Against this background, increasing the efficiency of water management is more than necessary, from its distribution to irrigation methods, not forgetting evaluation and controls. Only a multi-faceted approach to achieve this objective will do. Apart from a necessary improvement in methods, it probably means changing social and political attitudes if the resource is to be sustainable. It is in the agricultural sector, by far the thirstiest for water, that efforts must essentially be focussed.

Supporting new forms of supply

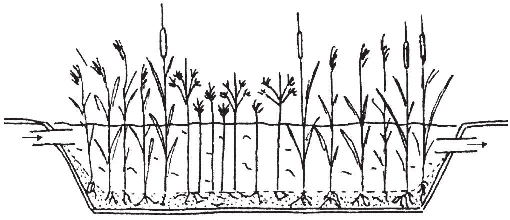
The supply policy, based on supply of water from large dams or massive pumping systems in the water table, is the subject of more or less justified criticism, sometimes forgetting that it has brought social and economic progress. Where would Egypt's economy be without the Aswan Dam? Nevertheless, the era of the first water revolution seems to be coming to an end because its limitations are now quite evident, as is illustrated by the overpumping of resources in the fossil strata in Libya, Egypt and Tunisia. Far fewer large dams are being built, even if a country like Turkey, which was lagging behind, managed to build 22 large dams in the GAP project. Structural adjustment policies also undermined the policy in the Maghreb of developing large works which no longer entirely meet the demands of agricultural systems in thrall to vast changes. For example, the development of these systems, conditioned by trade liberalisation, now demands a flexibility in the distribution of water which large water developments implemented by centralised policies do not encourage. This in part explains the development of small and medium-sized water systems based, in particular, on individual pumping installations which can use new technology (electrification, submersed pumps…). Meanwhile, it is becoming more and more difficult for public authorities to control water capture, which increases tensions between the actors, and the anarchic pumping practices contribute to the lowering of the water table.

Irrespective of the scale of projects, the supply of water (from dams, transfers or pumping) can lead to environmental imbalances. This is particularly true of the Nile (silting of the delta, disappearance of fish and salination of the river upstream from the dam). In the absence of effective drainage systems, irrigation water dissolves salts which then rises in the soil by capillary action (for example, in Syria). This salination is sometimes more immediate when the pumping takes place in the coastal strata where the fall in the piezometric level leads to penetration by sea water (Cyprus, Gaza, Libya). The supply policy is also burdened by the costs which it generates and which tend to rise the greater the distance between the resource and the users. Before it was decided to suspend the National Hydrological Plan (PHN), the projects for the transfer of water from the Ebro to the southern basins was costed at 4.5 billion euros.

New approaches are open to the Mediterranean, albeit more modest in terms of volumes supplied. The recycling of waste water in agriculture looks quite promising. Already practised in many Mediterranean countries such as Cyprus, Jordan, Tunisia, Egypt and Israel, it nevertheless needs to be improved. From an environmental point of view, this method offers a major advantage: as the majority of the nutritive elements (nitrogen, phosphorus and potassium) are absorbed by the crops, the recycling of waste water to the rivers and lakes reduces the risk of eutrophication, while limiting the use of chemical fertilisers. With the presence of dangerous elements, such as heavy metals, a sound regulatory framework for these methods needs to be put in place. In many countries, the standard applied is so restrictive that it makes the cost of purification prohibitive for farmers.

In the particular case of rural housing where, very often, connection to the public sewerage system is not possible, phyto-purification systems can be used to eliminate waste. These biological type treatments are based simply on the purification capacity possessed by certain plants, such as the common reed. Now adopted in many countries, in particular the United States for irrigation of golf courses, phyto-purification systems are not expensive and only require limited maintenance which can be done by nonspecialist staff. Their operation does not need large quantities of energy. Solar or photovoltaic panels can suffice. If the units are well designed, they give an almost total reduction in the pollutant content and considerable water recovery. Where the basins are not made properly impermeable, the aquifer can be polluted.

Figure 1 - Example of a phyto-purification installation



Among non-conventional resources, the process of desalination of sea water or brackish water also offers interesting prospects. There are already over 12,500 desalination plants in the world, with a variety of operating systems: Multi-Stage Flash (MSF), Multi-Effect (ME), Reverse Osmosis (RO), Nano Filtration (NF), etc. Bearing in mind the high energy requirement of these units and the arid character of their climate, it is not surprising that over 43% of world production of desalinated water is concentrated in the Arab Gulf States. Almost all the available fresh water is produced by desalination plants (the town of Jeddah in Saudi Arabia has the largest plant in the world with production of around 250,000 m^3 of water per day). For its part, Algeria is preparing to build two major desalination plants by 2009. The first, one of the biggest in the world, will be able to provide 500,000 m^3 of drinking water per day to the whole Oran region. The second, in Oued Sebt, 100 km from Algiers, will produce about 100,000 m^3 per day.

The development of this type of technology has allowed the building of increasingly efficient plants and a reduction in production costs to 0.49 euros per m^3 of water, although this is hardly enough, as it is still 4 to 9 times higher than the normal price. As can be seen in table 2, the factor which most influences the final cost is energy, consumption of which depends on the degree of salinity of the water and the type of fuel used.

Despite the high costs, this method seems to be effective for countries where the water deficit is worsening year on year. Above all, it has become a challenge for research which must make it more competitive. Researchers at the Lawrence Livermore National Laboratory (LLNL) are experimenting with new technologies which could reduce the cost of desalination by 75% using new membranes. According to Jason Holt, chemical engineer at LLNL, they could, in reverse osmosis processes, be available on the market in five to ten years. The research must also find ways of making the method more sustainable. The use of clean energy instead of fossil fuels, and especially the use of photovoltaic energy and wind power could be a solution in the future. For the time being, however, managers of desalination plants have little interest in investing in renewable energy due to the additional cost it represents compared with fossil energy.

Sea water, Israel's road to salvation

In the early years of the 21st century, Israel embarked on a long-term plan for the construction of several desalination plants along the Mediterranean (see table 3). According to forecasts by the Water Commissariat, desalination of sea water should provide 350 million m^3 by 2010, half the country's domestic consumption. In Israel, desalination does not only involve marine waters. Brackish waters are also desalinated and reused in agriculture.

Israel has thus forged itself a world reputation by developing state-of-the-art technology to produce fresh water from sea water. R & D work is now reducing the cost of desalination, while improving the quality of the water produced. Israel has therefore become a world power in water treatment and some observers already think that the country is on the way to becoming the *Silicon Valley* of water technologies. Proof of this is the Ashkelon desalination complex which is the largest and most modern in the world.

Source: Bendélac (2006).

Table 2 - Cost of desalination in the Mediterranean countries[3]

Type of installation	Salinity of marine water (ppm or mg/l)	Cost of installation € million	Cost of energy (electrical + thermal) €/m³	Cost of maintenance €/m³	Total cost of desalination €/m³	Impact of cost of energy (%)
MSF	30,000	190	0.58	0.02	0.66	88 %
ME	30,000	170	0.4	0.03	0.51	78 %
RO	30,000	140	0.23	0.08	0.49	47 %

Source: Data from Fisia-Italimpianti gruppo Impregilo, 2006.

Side by side with these desalination methods which, because of their cost, can only be used for drinking water consumption, the use of drainage water is another non-conventional source of water, in this case for agricultural use. Sadly, this often polluted and highly saline water is already used untreated. In Egypt and Syria, it is the chief cause of the growth in the concentration of salts in the soil. Apart from the decline in soil productivity, this water can put food security at risk. For all these reasons, the challenge here is to introduce simple treatments which can ensure a minimum water quality. It should be noted, for example, that Jordan, a country exposed to the most serious water stress in the world, has already resorted to this method with some success.

Promoting technical demand management

All sectors can contribute to saving water. In the domestic sector, merely inserting "flow reducers" in taps can give water savings of up to 50%. Studies in Brazil have shown that all that is needed is to regulate operating pressure during the day, depending on consumer demand (special valves automatically adjust the pressure by means of a control device) to reduce losses of drinking water in aqueducts and damage to distribution networks and inside houses. Without detracting from the importance of these savings, it is the agricultural sector above all which has serious scope for savings, especially in the countries in the South of the Basin where irrigation absorbs some 80% of the available resources. The prospects held out by certain irrigation technologies are encouraging and can very rapidly have positive effects on the other sectors. Reducing water used in agriculture by just 10% can double its availability for drinking or industrial use. At a time when irrigation is still often dominated by water guzzling methods, such as gravity irrigation, the spread of economical methods can lead to considerable water savings. Three irrigation systems predominate in the Mediterranean: sprinkler irrigation, micro-irrigation and subterranean irrigation.

- Sprinkler irrigation simulates the effect of rain by spraying water evenly over the ground. It is applied to crops by mobile, semi-fixed or fixed systems which spray water over a distance of up to 70 metres thanks to pressures ranging between 3 and

3 - The data are available on the website: www.water.treatment.unige.it

Table 3 - The Israeli desalination programme

Desalination sites	Annual water production (millions of m^3)	State of project
Ashkelon	100	In operation
Eilat and Dead Sea	35	In operation
Palmahim	30	Under construction
Hadera	100	Feasibility study stage
Shomerat	30	Feasibility study stage
Ashdod	45	Planning stage
Other	10	Planning stage
Total	**350**	

Source: Water Commissariat, Jerusalem.

5 bar. This method is only 80-85% efficient. The wind exerts a considerable influence not only on the distribution of the water but also causes the water droplets to break up, thus causing serious losses from evaporation, especially during the summer months. Another disadvantage is that the pressure requires considerable energy. This problem can be resolved, however, in areas where the topography allows collection tanks to be placed high above the areas to be irrigated, thus avoiding the need for pumping stations and ensuring adequate irrigation.

- Micro-irrigation is more economical. It consists of supplying water to the zone close to the roots or where it is needed. This avoids the need to water the entire surface of the land and reduces losses from evaporation. Thanks to the limited contact of the water with the soil, and with the aerial part of the plant, this type of irrigation allows the use of non-conventional water, including waste water. Despite its advantages, localised irrigation is only economically viable in the case of high-value cash crops. It is well suited to fruit trees (vines, olive trees, fruit trees, etc.), horticulture and nurseries, and can achieve much higher distribution efficiency than sprinkler irrigation, over 90% when installations are well built and properly managed with frequent irrigation and volumes of water strictly limited to the needs of the crop.

- Subterranean irrigation through discharge nipples or porous tubes laid 30 centimeters under the ground has numerous advantages. It is technologically simple, it is highly efficient and requires an operating pressure which may be less than 1 bar. However, while the initial investment is rather modest, the system requires considerable maintenance as solid particles or roots can infiltrate the nipples. In order to reduce these problems, tubes made of "Poritex", a geotextile material with special characteristics, are used both for surface micro-irrigation and subterranean irrigation.

Due to the costs involved, the use of any of these systems is not always commonplace. On the southern shore, these installations are prohibitive given the low agricultural incomes of most farmers. In Syria, where sprinkler irrigation costs between 3,500 and

Table 4 - Comparison between different irrigation systems

Caracteristic	Irrigation system				
	Poritex	**Drop-by drop**	**Micro-sprinkler**	**Sprinkler**	**Surface**
Distribution	Linear exudation	Localised drops	Localised rain	Rain	Flow
Pressure (bar)	0.2 ÷ 1	1 ÷ 2	2	3 ÷ 5	-
Difficulty of installation	None	Little	Average	Average	None
Filtration	Simple	Complicated	Normal	Low	None
Wind	Not applicable	Little effect	Perceptible	Perceptible	None
Evaporation	Low	Average	High	High	Very high
Fertigation	Yes	Yes	Possible	Not advised	Not possible
Percolation	No	Little	Little	Average	High
Maintenance	Low	High	Average	Average	None

5,000 euros per hectare, and drop-by-drop between 3,000 and 4,000 euros per hectare, the annual amortisation charge can be the same as the marketable production per hectare. The difficulties of adopting this type of installation combined with the lack of specialist engineers often compounds these economic problems. Nevertheless, some countries have made the change on a massive scale. In Jordan, the decision to modernise the irrigation systems in the Jordan valley was taken in 1990 and the shift from a system of distribution by gravity channels to a subterranean pressurised system was completed in 1996. Without making this country, with its extreme shortage of water, a model to be followed, it seems clear that the Mediterranean cannot do without these types of irrigation. In this field, cooperation between the countries of the South and the North, where these methods are well developed, is more necessary than ever.

Despite the efficiency and economical character of these methods, surface irrigation is still the most widely used in the Mediterranean today, especially by small farmers, as the hydraulic equipment required is basic, to say the least. Starting from the assumption that this form of irrigation which is cheap but wasteful of water will continue in the coming years, a series of improvements have been devised (furrows, levelling of the land, etc). However, they also require an enormous initial investment and constant maintenance and, here too, their use by farmers still requires various forms of subsidy and/or incentive.

The Mediterranean climate, characterised by long dry periods, allows the use of aridoculture and elimination of irrigation by maximising the efficiency of precipitation. Thanks to a series of soil improvements, evaporation from clay soils can be reduced by 70%. Likewise, the practice of reducing irrigation cycles can improve the efficiency of sprinkling. Rather than organising long watering cycles with copious irrigation of each plot, it appears to be more effective if the watering cycles are more frequent but less copious. The humidity is thus better distributed, which can save 25% of the quantity of water for the same result. Innovations also include the deficit irrigation method which consists of supplying crops with a minimal quantity of water rather than the optimal dose. In countries with low water availability, studies of this type of irrigation have given satisfactory results, especially for fruit trees (e.g. vines and olives). Research in this field should be encouraged, as is already the case in the EU with the DIMAS project.[4]

Genetics can be an important ally. In Tunisia, the genetic improvement of cereals concerned the search for earlier varieties which ripen earlier in the season and thus avoid an excessive period of drought. As they are not so tall, they are also less prone to disease. These varieties (in particular the Khiar 92 variety of durum wheat and the Inrat 69 variety, a cross with a local variety, Mahmoudi, and the Cypriot variety, Kyperounda) have led to a real growth in yields and production without, however, additional sowings or irrigation.

Lastly, one should not lose sight of the necessary progress in the efficiency of delivery systems, both for drinking water and irrigation, the first step in rationalising the use of water resources. In some countries, losses from pipes often exceed 50%. It should also be emphasised that micro-irrigation, sprinkler irrigation and sub-irrigation can give rise to losses if the networks are poorly constructed or if they are not properly managed. It must be admitted that, despite the efforts and financial resources employed, the performance of irrigated distribution systems (even pressurised systems) has fallen short of expectations throughout the Mediterranean Basin. The inadequate supply in terms of outflow and pressure at delivery points for customers (hydrants) can impair the uniformity of distribution of water on irrigated plots.

Demand management as core policy

Reducing water loss in agriculture is not just a matter of modernising installations or adapting better methods. Government policies can play a pivotal role in the pursuit of water savings and influence the production choices of a sector which, in the Mediterranean, can represent 80% of water consumption. Unfortunately, according to the WWF, EU subsidies and national governments discourage crops which require less water on the northern shore, such as olives and citrus fruits, while encouraging irrigated crops such as maize and sugar beet. This phenomenon, already a feature of the Arab countries, is aggravated by inefficient irrigation methods. More than ever, it is necessary to look again at subsidies for irrigation in water-starved areas, taking account of the water needs of crops, expressed in terms of "virtual water".

4 - DIMAS (Deficit Irrigation for Mediterranean Agricultural Systems) is a project being carried out with the collaboration of the Farmers for the Improvement of the Capitanata Region Association (Italy), the University of Cucurova (Turkey), the Agricultural University of Athens (Greece), the National Agronomic Institute of Tunisia (Tunisia), the University of Jordan, the National Agronomic Research Institute of Tunisia (Tunisia), the Hassan-II Agronomic and Veterinary Institute (Morocco) and the Mediterranean Agronomic Institute of Bari (Italy).

In future, decision-makers in the Mediterranean countries must incorporate this notion of virtual water in trade if they want to reduce the pressure on water resources. J. A. Allan has shown that in water-deprived areas, water wars were avoided thanks to trade in agricultural goods and amounted to virtual transfers of water from the exporting countries to the importing countries. The water needed in the production process varies, depending on the type of plant (cf. table 5) and animal species. While the concept may seem quite simple, measuring virtual water is very complex. In plant production, the quantities incorporated (*embedded water*) in a production process differ from one climate to another and from one variety to another. In the animal field, the variability in volume is also very large. The quantity of virtual water needed depends on the climate, which determines the animals' level of water consumption, and also on feed intake. To accommodate this variability, median estimates are taken.

Table 5 - Water needs for certain crops in Apulia (Consorzio per la bonifica della Capitanata)

Crop	Type of irrigation	Period of irrigation	Seasonal water* needs (m^3/ha)
Artichoke	Sprinkler or micro-irrigation	July-June	6,000
Sugar beet	Sprinkler	March-July or October-June	4,000-5,500
Industrial tomato	Micro-irrigation	April-August	4,000-5,500
Maize	Sprinkler	May-August	4,000-5,500
Sorghum	Sprinkler	May-August	3,000-4,000
Peaches	Sprinkler	April-June	3,000
New potatoes	Sprinkler or micro-irrigation	January-May	3,000-4,000
Green beans	Sprinkler or micro-irrigation	May-July	3,000-4,000
Lettuce	Sprinkler or micro-irrigation	October-November and February-March	1,800-3,000
Vine	Sprinkler or micro-irrigation	April-August	1,800-3,000
Sunflower	Sprinkler	April-August	1,800-2,600
Olive	Micro-irrigation	May-September	1,000-2,000
Soft wheat	-	-	Irrigation de secours

* *These values are closely linked to the characteristics of the soil, the method of irrigation and market demand.*

Given the highly variable needs of production, countries with water shortages have every interest, *a priori*, in producing dry vegetables and importing cereals and meat. However, as meat generates a high added value and it is primarily the cereals contained in feeds which raise the virtual water of a kilogram of meat, one may well wonder if it would not be possible for an arid country to import cereals and transform them there. This seems to be Tunisia's view.

If the Mediterranean countries take account of this virtual water, the subsequent productive specialisation of each shore and its clear socio-political implications must be monitored. The prospect of a trade in virtual water must be integrated in intra-Mediterranean agricultural trade which up to now has been little marked by the seal of cooperation. More than ever, Euro-Mediterranean populations are duty bound to promote an adequate framework for their agricultural trade. Water is a problem for all Mediterranean peoples, on all its shores. It must therefore be a major theme of the Euro-Mediterranean debate.

When it comes to governance of water, the integrated management approach seems destined to spread since it is not only a way of preserving the resource, both in quantitative and qualitative terms, but can also ensure broader access while safeguarding aquatic ecosystems and biodiversity. The geographical unit best suited to such management is the catchment basin which is a hydrologically closed space, i.e. no flows penetrate from outside and all excess precipitation evaporates or flows towards the same outlet (e.g. a river).

The time is also more than ever ripe to consolidate associations of water users. In many Mediterranean countries, irrigation systems managed by them are more efficient than those managed by central agencies even if the latter still have to exercise overall supervision over the activities. The creation of groups of irrigators does not get rid of disputes between farmers. As, in the Mediterranean, farms served by distribution networks are often small (one hectare or less), a single hydrant serves several farms which may dispute the volume shared. As well as being a challenge at international level, the sharing of water also affects very small areas. Against a background of shortage and exacerbation of disputes, some countries have introduced measures to prevent social tensions. In Apulia, a new system has been tried in the last few years with evident success. In water distribution cooperatives where the water is supplied under pressure, the amount taken by each customer of the cooperative can easily be measured by means of an electronic card which is inserted in the hydrant. Once the allocated amount of water has been delivered, the customer can apply to the manager to obtain a further quantity if, of course, it is available. For the system to operate properly, the role of the managers is, of course, crucial. It should be noted that the cost of this installation is comparable to that of the traditional installations currently in use.

Management of water consumption also involves the application of tariffs to ensure that the actors behave responsibly. Apart from the fact that it allows recovery of the costs of collection and supply of water, several experts emphasise that the most efficient way of avoiding water losses in agriculture is to apply tariffs which discourage excessive consumption and, consequently, maintaining inefficient irrigation systems. In reality, in many cases, this has not always had the desired effect. The policy can, in fact, drive farmers to abandon land or, worse still, use water from other sources, sometimes to excess, rather than take it from the cooperative installations. This tariff system in part explains why Spain has some 510,000 illegal wells, Italy 1.5 million (300,000 in Apulia alone), and Turkey 50,000 wells just in the Konya Basin (Isendahl *et al*, 2006).

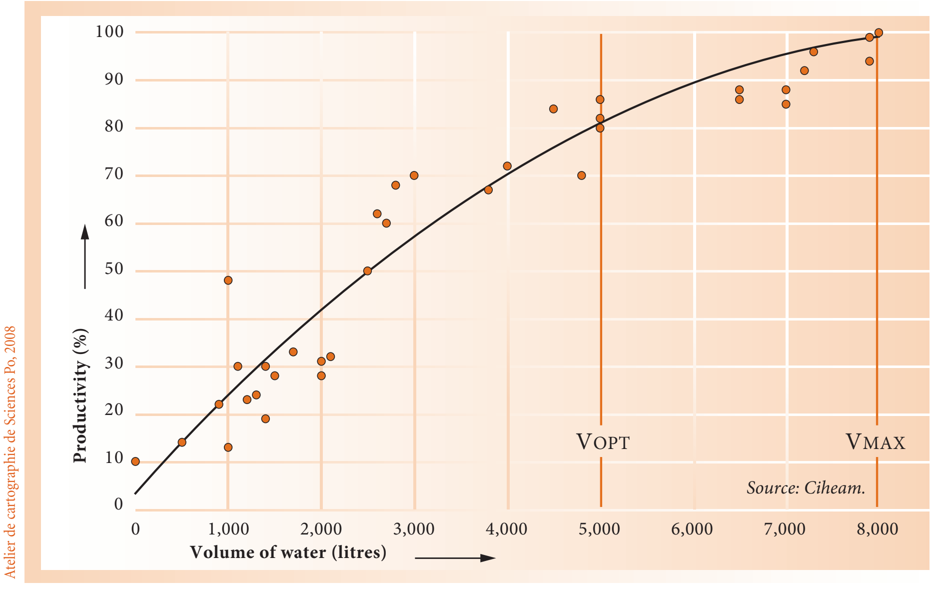
Despite this limitation which underlines the importance of a water policy, a system of tariffs should not be abandoned. Tunisia provides a fine example of success in this regard. In that country, the trend is towards a gradual annual increase in the price of water, both in irrigated areas and in community water supply networks. The objective of progressively encouraging water savings is clearly stated. The reduction in consumption is all the more remarkable in that it is not necessarily accompanied by a fall in agricultural production or general activity. This increase in the price of water therefore gave rise to a healthy response in the form of investment to improve the profitability of the use of the resource: more effective irrigation methods, renovated water networks, awareness among various users and changes in behaviour, etc.

In general, it seems preferable to apply tariffs based on volume with progressively rising thresholds. FAO is much in favour of threshold-based tariffs, the threshold volume being the minimum volume allowed to meet the water needs of the crop. This system could be used for water drawn from aquifers related to the maximum low-water volume and the speed of replenishment. With these tariff thresholds, the chief objective is to maximise farmers' incomes and not production. In return, farmers try to make water savings because they offer an economic benefit (Chart 1).

Water geopolitics: the Mediterranean case

Water is becoming scarce in the Mediterranean and sharing it sometimes leads to disputes. Unfortunately, international law does not really provide an adequate framework for the settlement of disputes. Theories on water rights have emerged on the question of the cross-border use of water. It has to be observed, however, that they are obviously projections of national interests. Absolute territorial sovereignty or the Harmon doctrine, named after an American judge called on to rule on the crisis between Mexico and the United States at the end of the 19th century, emphasises the geographical position. In order to irrigate land in the South-West, the United States began diverting the waters of the Colorado. This was condemned by Mexico in 1895, claiming that the user rights of the Mexican farmers pre-dated those of the North Americans. The American Government presented its argument inspired by Harmon that the fundamental principle of international law is the absolute sovereignty of each State, against all others, over its territory. The jurisdiction of the State over its own territory is necessarily exclusive and absolute. Its only limits are those it imposes on itself. As the converse of this theory, one finds that of absolute territorial integrity, whereby each state must allow a river to follow its course. In the Nile Basin, Egypt used this argument to assert its rights over a disputed river. The principle of prior appropriation also originates in North America, since it was conceived to assert the ownership rights over water of the prior user who developed it. Implicitly evoked by States such as Syria, Iraq and Egypt in the name of very ancient exploitation of the waters of the Nile and Mesopotamia, it is also invoked by Israel on the pretext that the first Jewish settlements had exploited the waters of the

Chart 1 - Productivity curve for a generic crop



West Bank aquifers. None of these three doctrines has been enshrined in international jurisprudence. It is on the basis, one may imagine, of their own interests that States opt for a particular legal doctrine. The upstream countries refer to the Harmon doctrine, still called "absolute territorial sovereignty", while the countries downstream have agitated for the principle of absolute territorial integrity or prior appropriation.

One international right has nevertheless emerged as a compromise between these positions, notably the Convention on the Law of Non-Navigational Uses of International Watercourses, adopted by the United Nations General Assembly on 21 May 1997, reflecting the will to establish homogeneous and coherent legal principles to alleviate the multiplicity of conflicting legal theories. In 1970, the United Nations General Assembly recommended that the International Law Commission should take up "the study of the law of the non-navigational uses of international watercourses with a view to its progressive development and codification". The principle adopted by the Commission's lawmakers was that of the "reduced territorial sovereignty principle". The State is free to conceive projects to exploit water flowing through its territory, but must endeavour not to harm the interests of other riparian countries along the same watercourse and its tributaries. The text also defends the catchment basin approach centred on three basic principles: "utilization in an equitable and reasonable manner" (article 6), "obligation not to cause significant harm" (article 7) and "obligation to cooperate" (article 8). It allows wide scope for interpretation and may encourage differences of analysis. Countries that lag behind in developing their river (Ethiopia and the Nile, for example) can invoke article 6, while others rely on article 7 stipulating the prohibition on causing harm, for example those who have developed the watercourse before the others, such as Egypt, Syria and Iraq, which tend to be downstream.

The Convention sets out other principles such as the obligation to share data and inform about actions which may change the watercourse, for example, in the case of closing of a dam in order to fill it, a principle which is more honoured in the breach. Above all, it highlights the need for cooperation in the case of a shared catchment basin. Indeed, and bearing in mind the very woolly wording, this aspect seems to be the best approach to a solution in the case of disputes between riparian States. As water management is not a zero-sum game, they no doubt have much to gain by managing the same catchment basin jointly and incorporating the needs of each in a truly transparent manner (the riparian countries of the Senegal River have already done this). In the Mediterranean, where rivalries for access to water resources are sometimes keen (as in the Euphrates Basin or the Jordan Valley), this approach is inherently more difficult. However, cooperation encourages solidarity and lays the basis for strengthening political partnerships.

Observing, planning, legislating: three challenges for the protection of Mediterranean soils

Currently, only 13% of the soils of the Mediterranean can be considered suitable for agricultural use, the remainder being shared between pasture, forest, scrub, urban areas, rocky areas, plains and deserts. This situation is the consequence of the rapid changes since the 1950s with, on the one hand, intensification of agriculture allowed by irrigation and, on the other, sometimes massive urbanisation of rural areas which accelerated the degradation of the soil exacerbated by lower precipitation and longer periods of drought. Much land began to be afflicted by a process of desertification, defined as the loss of soil productivity and withering of the plant cover in dry zones rather than the advance of the desert.

Fortunately, knowledge of soil degradation and its complexity has grown. Strategies have been perfected, especially through national initiatives or the ratification of specific agreements between countries (such as the United Nations Convention to Combat Desertification). The need for a coherent approach to soil protection was recently included in the EU policy agenda which introduced the problem in the Thematic Strategies to be developed in the Sixth Four-Year Plan. The realisation of the multipurpose character of soils means that they can be seen not merely as simple supports for traditional agriculture, but also as filters, barriers against pollution of underground water, conservers of biodiversity and, most important today, places for the collection in organic form of carbon dioxide from the atmosphere.

In developing a soil intervention policy, one must be aware of the extreme spatial and temporal variability, which makes the problem of protecting this resource particularly complex. It must also be borne in mind that with the slow pace of pedogenetic processes, soils are practically a non-renewable resource over a time span of fifty to one hundred years. It is thus urgent and vital to measure the degree of degradation of Mediterranean soils and above all to anticipate the scale. Researchers must provide decision-makers with concise indicators containing the most precise information possible on land resources.

Among the initiatives intended for defence of the environment, the OECD recently defined a series of indicators, "*Driving Forces State and Response*" (DSR framework) which is easy for policy makers to use. It lists the causes of changes in the soil and the landscape and agro-environmental indicators for rural areas (density of road networks, extension of areas used by organic agriculture). The "*state*" describes the effects of these parameters on soils, and the "*responses*" the actions that could be taken in terms of new soil policies to mitigate and control the "*driving forces*". The pressures (unit of production per unit of agricultural land employed, average consumption of pesticides) and the "*impacts*" describe the interconnections between economic activities and the behaviour of society which have an influence on the environment in general. New initiatives to develop state, *impact* and *response* indicators relating to soil protection are in the pipeline.

In order to provide decision-makers with better information, a database on the chemical-pedological characteristics of soils is essential. In particular, it would allow a geographical analysis of soil degradation so as to prevent it more effectively. At present, there is no exhaustive soil database for the Mediterranean Basin. The information is available everywhere, but the amount and geographical coverage varies depending on the country or region where it was collected. To promote these databases, therefore, a network of information needs to be created (pedological, hydrological, climatic, etc.) prepared at different levels, from regional level to the Basin as a whole, based on standard definitions so that it can easily be assembled and compared with data for other countries. This database must also be accessible to everyone operating in the sector, simple to manage and easy to update reasonably quickly.

The European Commission and the European Environment Agency (EEA) decided to work together along these lines by developing and setting up information collection centres for each of the major environmental themes. Four institutions were identified to run these observatories: the EEA, Eurostat, the Joint Research Centre (JRC) and Directorate General for the Environment (DG ENV). A new information centre, the European Soil Data Center (ESDAC) will be based on a tried and tested system (Eusis) developed in the last few years by the JRC. It will be linked to other international centres in order to contribute to the World Soil Information Database developed by the International Soil Reference and Information Centre (ISRIC). Using the information gathered, it will be possible to predict probable pedological trends and thus enhance environmental governance. It marks a real qualitative leap forward compared with the European Union and FAO databases used hitherto.

Clearly, land potential needs to be monitored, but the waste of space and thus soils also demands that States should act more decisively in the short term to define land use. Spontaneous and unregulated urbanisation constantly encroaches on a crucial resource. An analysis of land use patterns shows that every year new land is artificialised and very little is returned to its original purpose. Apart from the quantitative constants, the major problem is the irreversible loss of good agricultural land. The more land a country loses, the less its chances of developing the extensive agricultural methods need to produce at competitive prices, reduce the dangers of pollution and conserve the agronomic fertility of the soil.

The anarchic spread of urbanisation by 2020 would increase tensions in the Mediterranean Basin, aggravating the socio-political situation in the region. Reviewing and revising urban planning tools is an absolute must. The difference in the development of two regions closely related both from the standpoint of natural conditions and level of development, the Italian Ligurian Riviera which has retained its agricultural heritage and the Côte d'Azur which has not, shows that agricultural land need not necessarily be swallowed up by urban sprawl. In the South, albeit with modest success, Egypt shows in the construction of its new towns that it is possible to spare the best agricultural land. Algeria also appears to want to implement such a policy. The fact remains, however, that solving the problem of conservation of agricultural land and periurban rural areas continues to be a matter of urgency.

The crossroads

The analysis of natural resources has shown the challenges which must be faced by the Mediterranean Region. Whatever the resource (soil, water, energy), it is a matter of managing growing shortages. The global scenarios up to 2020 flow from the ability to take this evidently increasing scarcity into account. Bearing in mind the strength and extent of the response, there are clearly many such scenarios ranging from passive attitudes to the truly forward-looking, combining action and foresight.

In the case of a passive posture, 2020 looks pretty gloomy in terms of natural resources. Some 70 million people in the Mediterranean would be suffering from water shortages in 2025 (less than 500m^3 per capita per year). The use of non-sustainable resources, i.e. from fossil sources or over-exploitation, would inevitably rise (by up to 30% in Malta or Libya), and the less well-off countries will be hardest hit by structural shortages. Drinking water supplies would be guaranteed for rich, urban populations to the detriment of poor and/or rural communities. As cultivable land becomes increasingly scarce, agriculture will continue to be entrenched in areas already short of land and water. The agricultural sector would also suffer from climatic warming and the proliferation of extreme weather conditions.

In countries with a large agricultural population (Egypt especially), such a scenario could lead to more riots like those which occurred in the 1990s with the agrarian counter-reform or in the Summer of 2007 with failures of drinking water supplies in the villages of the Delta. Already in evidence, the agricultural gulf between the North, still well endowed with resources in 2020, and the South and East very deprived by that time, could grow. Against the background of a globalisation not offset by strengthening of Euro-Mediterranean trade links, it is by no means certain, indeed far from it, that the deepening of the deficit in the South and East will benefit the North, in competition as it is with the United States and countries like China and Brazil which are emerging on to the agricultural scene. It will not be energy output, which is of little benefit to the South and East Mediterranean Countries apart from Algeria, which will reduce the scale of the gulf between the two shores. On the contrary, emerging from a degree of lethargy in this field, the countries of the northern shore, albeit modestly, have already passed an energy crossroads. By adopting first generation biofuels, the northern shore could add to the rising price of food production caused by the displacement of food production from the land.

At the heart of Mediterranean societies, competition for land and water is already in play, between farmers, between town and country, tourism and agriculture, etc. In this very gloomy scenario, there is no doubt that water and land disputes, both small scale and large, would persist and geo-political tensions could arise against a background of diminishing fossil energy. As for the environmental dimension for 2020, one could expect very worrying points of no return.

However, this scenario, marked by impoverishment, instability and violation of ecosystems, is not inevitable. Given the urgency of the situation, decision-makers could still react and redirect their policies. To do so, they will have to firmly state the new directions of public policies, in terms of alternative supply (desalination and re-use of waste water, renewable energy), rationalisation of demand for water and energy (savings are beyond a shadow of a doubt the best water reserve), and also soil protection in terms of quantity (land) and quality (productivity). Time is short. Better to change course now, the effects of which would be perceptible in 2020 and intensified thereafter. One might then see the emergence in the Mediterranean of a more sustainable agricultural activity yet without diminishing its income-generating role.

In this scenario, which has to be voluntary, there must necessarily be investment in renewable energies, especially second generation biofuels which do not have the same impact on cultivable land (this should become much more apparent in the next ten years). Likewise, new sources of water supplies (desalination, re-use of waste water) will be the focus of particular attention, given that success in the treatment of sea water or brackish water will be conditional on the ability to remove the energy burden, and serious efforts must be made to save water.

While national and international public policies must incorporate these priorities, the actors involved are at different levels: governments, local authorities, consumers, farmers (irrigators' associations, producer groups, etc.), industrialists and scientists. As elsewhere, the mobilisation of the Mediterranean regional political framework should not be overlooked. In 2005, at the proposal of the Mediterranean Commission for Sustainable Development (MCSD), the contracting parties to the Barcelona Convention adopted the Mediterranean Strategy for Sustainable Development announced at the Johannesburg Summit in September 2002. Moreover, the first field of action adopted as a priority was to improve the integrated management of resources and especially demand for water.

There is no lack of opportunities for cooperation. Research into saving resources will be more effective if the work is shared. The sometimes heavy investment calls for economies of scale which are more achievable if States are partners in scientific research. As to the intangible capital from research, there is no doubt that its development is all the more certain if it comes from networks of teams with a wealth of multiple and complementary skills. Other aspects can be used to mobilise the regional framework: reflection on the trade in virtual water, which should underlie the Mediterranean trade debate, is an obvious example. Likewise, dialogue between States will be a strategic vector in progress towards sustainable management of water resources. These action lines show that a fatal catastrophe affecting Mediterranean natural resources is not inevitable. If group and individual interests are put aside or at least countered by a clear political will, a sustainable development strategy can be gradually put in place.

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