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'Climate change: a challenge or a threat for water management'

Climate change and water management and protection plan in Emilia-Romagna region (Italy)

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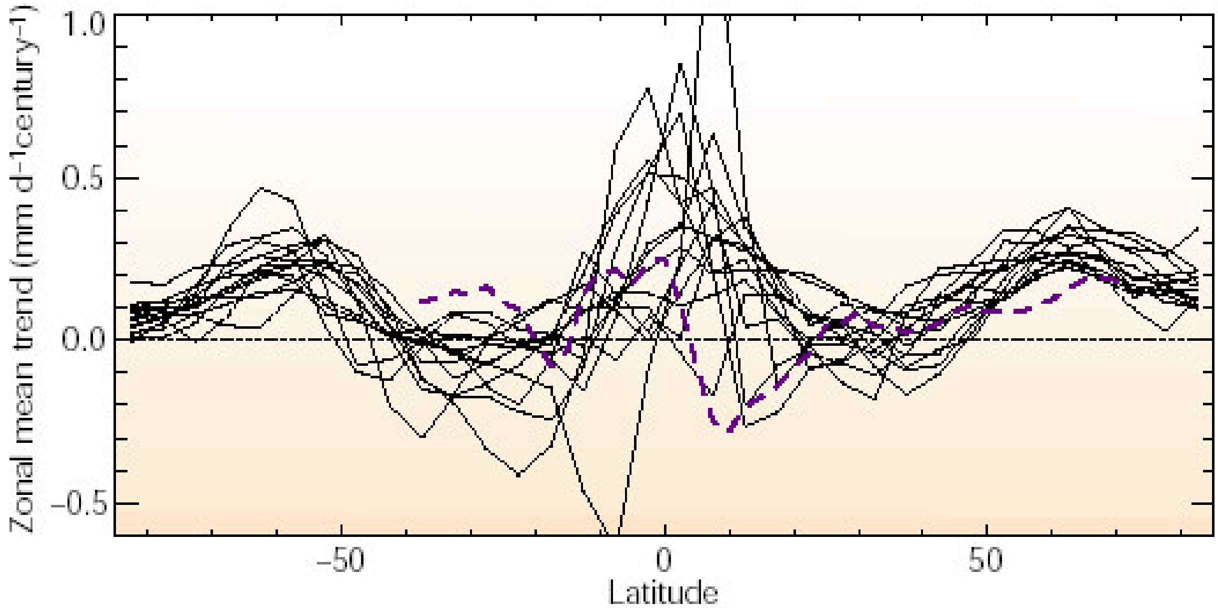
Abstract
The climate change is in action, and it will accompany us in the future. It will have a meaningful impact on the water cycle and the management of the water resources. In spite of many previsional models and many evolutionary scenarios, the uncertainty about data and projection is still remarkable. The adaptation to the climate changes demand to the water planning a continuous comparison with the risks and the uncertainties connected. It will be necessary to reduce the vulnerability of the civil society in front of the "new" hydro-meteorological trend (characterised by one greater variability of the events, and by an increment of those defined "extreme"), by moving towards the protection and recovery of the natural ability of the ecosystems on the mitigation of the effects, and towards the water demand government.

Introduction
The IPCC Third Assessment Report (TAR) suggests that, due to the increase in concentration of green-house gasses the increase in mean surface temperature implies an increase in the intensity of the hydrological cycle. As we read in the TAR, since the time of the SAR, annual land precipitation has continued to increase in the middle and high latitudes of the Northern Hemisphere (very likely to be 0.5 to 1%/decade), except over Eastern Asia. New analyses show that in regions where total precipitation has increased, it is very likely that there have been even more pronounced increases in heavy and extreme precipitation events. The converse is also true. In some regions, however, heavy and extreme events have increased despite the fact that total precipitation has decreased or remained constant. This is attributed to a decrease in the frequency of precipitation events. The TAR projection of future changes in precipitation indicate that it is likely for precipitation to increase in both summer and winter over high-latitude regions. In winter, increases are also seen over northern mid-latitudes. For the Mediterranean area the projection in Scenarios such as A2 shows winter precipitation unvaried and decreasing in summer time, for the scenario B2, which has lower fossil fuel emissions as well as lower SO 2 emissions, projections shows no change in winter and inconsistent sign in summer.

In a recent article, Allen *et al*. (2002) stresses that although the large-scale temperature response to climate change forcings is predicted to be relatively smooth (usually with the same sign everywhere), precipitation varies much more in space and time and is notoriously much harder to simulate correctly in models. It is no surprise then that predicted changes in local precipitation vary considerably both in space and between models. Figure shows zonal mean precipitation trends over the 70 years to CO_2 doubling in the CMIP-2 ensemble (the second Coupled Model Intercomparison Project) and observed trends in terrestrial precipitation over the past century. Each thin solid line is for a member of the CMIP-2 ensemble (forced with CO_2 changes alone), whereas the thick dashed line is the observed trend over the twentieth century from land based observations.

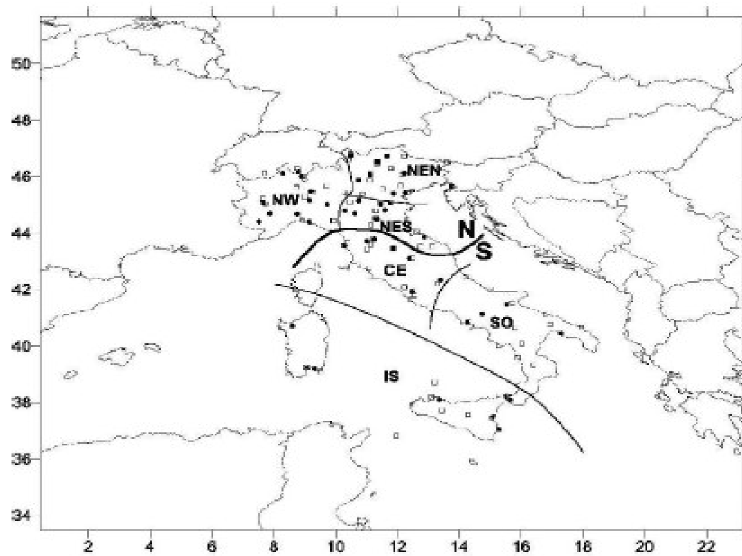


Emilia-Romagna (around 44° latitude) is a region situated in Northern Italy, in the valley of the River Po, bounded by Apennine Mountains to the South and the Adriatic Sea to the East. The climatic conditions of the region are related to the climatic general conditions of the Po Valley (surrounded by the Alps and the Apennine) and are mostly influenced by the mountains and the sea, this leading to a high spatial variability of the precipitation fields. For our region, but also for the Mediterranean zone, the water uses for irrigation are generally predominant. An analysis about the growing CO2 emissions impact is crucial. The SAR stressed that the temperature and CO2 emissions growing could increase the plant productivity.

About this it was undertaken under the UK Climate Impacts Programme (UKCIP) the report "Gardening in the Global Greenhouse: the impacts of climate Change on Gardens in the UK" (Bisgrove *et al*., 2002). Plants grow and develop in response to a range of stimuli but especially to the availability of carbon dioxide, water and mineral nutrients and to the quality and quantity of light. Most of these stimuli will be affected directly or indirectly by climate change. If other factors remain favourable, increased carbon dioxide concentrations will lead to greater rates of photosynthesis in plants. Moreover the plant manages its intake of carbon dioxide and its control of water loss by the same mechanism, the opening and closing of its stomata, the plant responds to water stress by closing its stomata. Conversely, if the supply of carbon dioxide is greater than the plant can utilise, it will react by closing its stomata and it will, in so doing, reduce its water use. Decreased stomatal aperture under conditions of elevated carbon dioxide also leads to an increased resistance to water loss from leaves. Thus, as carbon dioxide concentration increases, the water use efficiency also increases. This suggests that the rate of evapotranspiration decrease under conditions of elevated carbon dioxide.

The climate change in Italy

In Italy there are only some studies of interest and one finalised at the Third Italian Communication to the UNFCCC, "*Evoluzione del Clima ed impatti climatici in Italia*". For the past the communication confirm the TAR, with differences from North and South of Italy. Strong problems for Italy are at South water stress and desertification meanwhile at North could be a stronger "run-off" and the consequent floods, soil erosion etc. The study is based on an important Paper (Brunetti *et al*., 2004a). The Paper summarises activities within a broad-based research program for the reconstruction of the evolution of Italian climate in the twentieth century. The series included in the database are coming from 46 stations uniformly distributed in Italy. All series include **monthly mean values** of daily maximum (Tmax), mean (T) and minimum (Tmin) temperatures and monthly total precipitation (P), part of them include daily observations too. Monthly series were divided in two groups corresponding to two climatically homogeneous areas - Northern Italy (N) and Central-Southern Italy (S) - that are, respectively, the continental and the peninsular zones of Italy.



The analysis covers the years between 1867 and 1996, and shows the seasonal and annual trend of the Parameters of Temperature (T°C/100y), Precipitation (Pmm/100y) and diurnal temperature range DTR (°C/100y).
Yearly and seasonal temperature, precipitation and daily temperature range trends for northern and southern Italy (period 1867-1996) defined by linear regression coefficient (b) and associated error. Bold numbers: significance level greater than 99%, italic numbers: significance level greater than 95%.

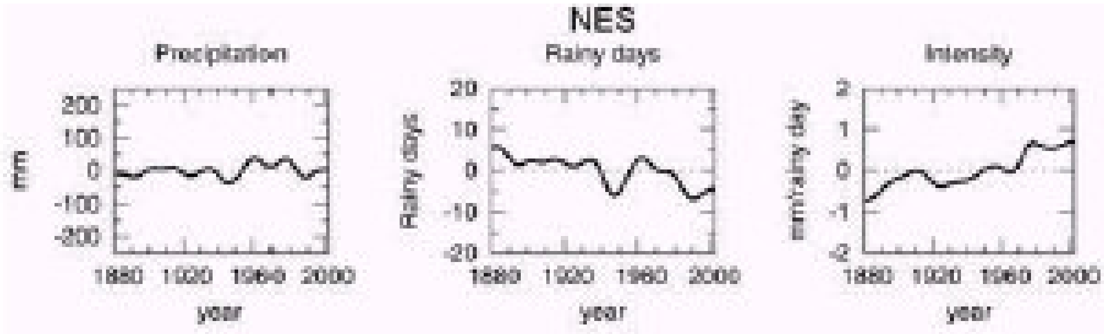
		$b \pm \sigma_b$		
		T (°C/100y)	**P** (mm/100y)	**DTR** (°C/100y)
Winter	**N**	**0.7±0.1**	*8±7*	*-0.10 ± 0.07*
	S	**0.9±0.1**		
Spring	**N**	**0.3±0.1**	**-20±7**	**0.38 ± 0.01**
	S	**0.4±0.1**	**-39±5**	
Summer	**N**		**-7±6**	*0.20 ± 0.08*
	S	**0.5±0.1**	**-17±4**	
Autumn	**N**	**0.5±0.1**	**-28±8**	
	S	**0.8±0.1**	**-33±6**	**0.29 ± 0.06**
Year	**N**	**0.4±0.1**	**-47±17**	*0.17 ± 0.07*
	S	**0.7±0.1**	**-104±12**	*0.09 ± 0.06*

The principal results for precipitation are as follows:

- The number of Wet days (WDs) in the year has a clear and highly significant negative trend all over Italy. It depends mainly on the winter, the season which accounts for about 50% of the N decrease, and about 75% of the S one.
- Besides the reduction in the number of WDs, there is a tendency towards an increase in PI. This increase is globally less strong and significant than the decrease in the number of WDs, and it is not concentrated in one specific season. It is worth noticing that, in winter, the PI trend is positive, but very weak, in N and negative in S.
- In N, the increase in PI is mainly due to a strong increase in precipitation, falling into the highest class-interval, whereas in S, it depends on a larger part of the WD amount distributions.

For Temperature T there is a growing trend at North and South, respectively of 0.4°C e 0.7°C/ 100y and in summer at North the increase is very low and P in the same season there is not a trend.

Moreover an other recent study (Brunetti *et al.*, 2004b): using a new data set of 45 **daily precipitation series**, covering quite uniformly Italian territory for the period 1880–2002, was recovered. The principal results are that Total Precipitation shows no trend in northern regions (NW, NEN and NES) and a significantly negative trend in southern regions (CE and SO) with a decrease of about 10% per century in total yearly precipitation. The other results show a negative significant trend in the number of wet days all over Italy, and a positive trend in precipitation intensity, which is significant only in the northern regions. The negative trend in wet days has persisted since the end of 19th century and is due to the marked decrease in the number of low intensity precipitation events. An increase in the number of events belonging to the highest intensity class interval was observed too, but only in northern regions.



For our region, the Regional Meteorological Office presented an analysis for summer and winter precipitation over Emilia-Romagna (Cacciamani *et al.*, 2001). The data used in the study are the monthly precipitation amount from 40 rainfall stations located in Emilia-Romagna covering a period from 1922 to 1995. The stations are approximately uniform distributed over the region and their time series could be considered long enough to identify the climate signal concerning the main features of temporal and spatial variability of precipitation. The total amount of summer/winter precipitation was computed using the monthly quantity of precipitation from June, July and August (JJA) and, respectively December, January and February (DJF). An increasing trend of the summer precipitation over the 1922-1995 interval (considering 17 stations) was found in the northern, central and eastern part of the region studied. The climate signal was also present over a smaller area when the analysis was repeated for the 1948-1995 interval. Increasing the number of stations up to 40, a positive trend was detected in the whole region and new small areas with a significant upward trend appeared in the southeastern area. This result shows that the climate signal related to the trend is strongly dependent on the time interval and the density of stations. A similar analysis was performed for the winter precipitation. A significant decreasing trend was detected in the whole region, more significant in *1960-1995* interval, when data from each station was analysed. Trend analysis applied for each winter month evidences that the *decreasing* is significant especially in *Januar*y.

Planning strategy

On 21 March 2001 the Minister for the Environment, launched the Agency's new water resources strategy for England and Wales. The Environment Agency (EA) is the statutory body with a duty to secure the proper use of water resources in England and Wales. The strategy looks some 25 years ahead and considers the needs of public water supply, agriculture, commerce and industry, as well as the environment. The strategy examines the uncertainties about future water demand and availability including the potential effects of climate change. The Agency's approach to water resources planning is based on four main principles. Sustainable development, the "twin-track" approach, robustness to uncertainty and change and the precautionary principle. The "twin-track" approach takes a balanced view, seeking the efficient use of water while bringing forward timely proposals for resource development where appropriate. The approach implies that, as more resource development is required, increasing effort must be applied to the efficient use of water.

Climate change has an effect on three elements of water resources planning:
• demand for water;
• availability of water;
• impact on the natural environment.

Relationship between weather and water use is not perfect, so it is not possible to be absolutely certain about how climate change will affect demand. In the light of such uncertainties, the proposed strategy is flexible and phased. The final decisions on many of the later actions need to be made some way into the future, when there is more certainty about the result of earlier actions. This means that the monitoring of progress is essential.
In her strategy, the EA has assumed that over the next 25 years most public water supply systems will retain their existing yields. The Agency assumed also an increase in the water demand by household for personal washing and water gardening, about 180 Ml/d by 2025, and forecasts of industrial demand do not need to be modified. Over the next 25 years, climate change will be one of many challenges facing agriculture. Given that the EA results are preliminary they have not included climate change in the assessment of incremental demand.

Changes in climate will change flow regimes and therefore the availability of water for abstraction. All of the current UK Climate Impacts Programme (UKCIP) scenarios suggest on average more annual rainfall throughout England and Wales, with less summer rainfall in the South. Higher temperatures mean that potential evaporation rates will probably increase. In his strategy, the EA has assumed that over the years most public water supply systems will retain their existing yields. This is a reasonably conservative assumption, as most systems depend to a great extent on the storage of winter water in either aquifers or reservoirs.
The strategy is also particularly strong in terms of promoting prudent use of natural resources, which is also advanced by many of the options within the regional strategies. Examples of these actions include bankside storage schemes which make use of available winter flows and water efficiency measures such as increased leakage control, domestic water metering, water audits and water use minimisation in industry. All of the regional solutions place significant emphasis on these water efficiency measures.

Hoff (2003) suggests to use an approach 'no-regret", (measures no regret are those whose economic rate of return justifies them regardless of future changes in climate). Integrated water resource management requires a combination of four categories: *supply system management*; *demand management*; *resource operation*; *risk management.* We tried to use this approach and the EA Twin track strategy in the Water protection Plan in Emilia-Romagna.

Regional planning
In our region, the total withdrawals at the end of the 70' were estimated (in millions of cubic meter, Mcm):

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	350	240	150	740
Surface water.	negligible	290	852	1142
Total	350	530	1002	1882

Studies for the middle of the 80' gave:

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	310	227	193	730
Surface water	170	337	681	1188
Total	480	564	874	1918

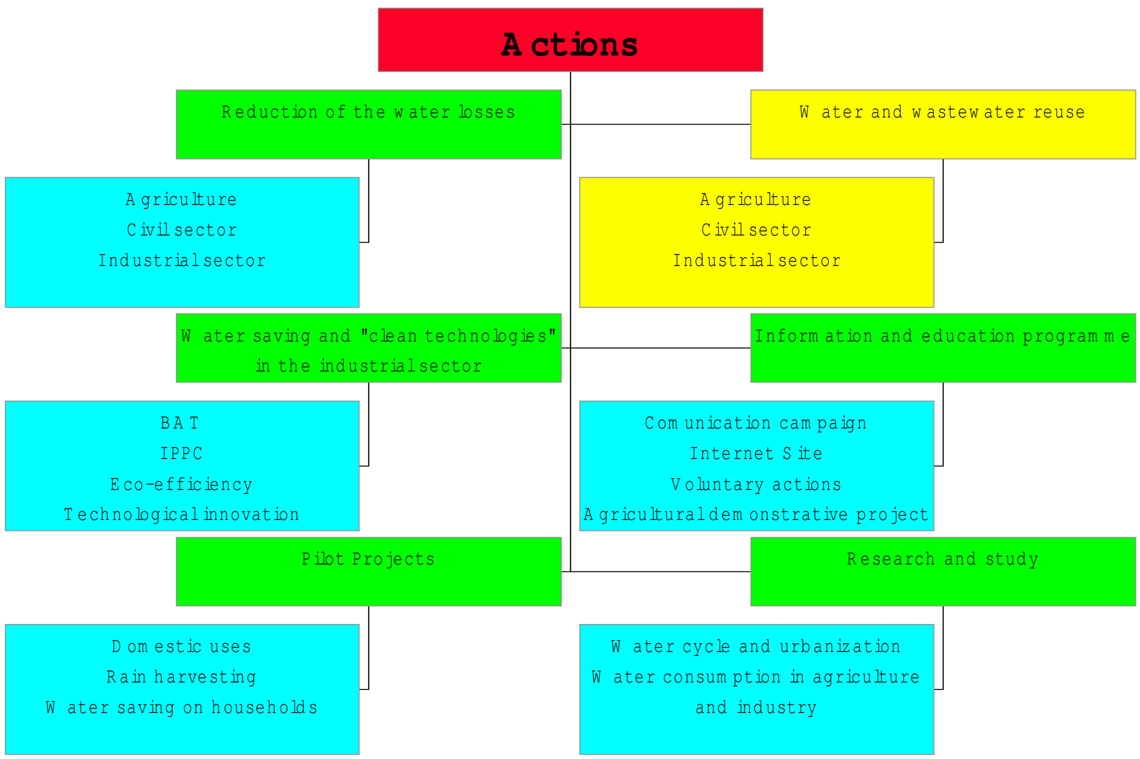
Our last (2000) data are:

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	282	171	222	675
Surface water	205	62	1183	1450
Total	487	233	1405	2125

We observe a modest increase of the total withdrawals, with a strong replacement from the industrial uses to the irrigation uses and, partially, to the civil uses. There is an important decrease in the groundwater withdrawals. Is interesting also to note that the civil withdrawals are stable form the 80'. The increase in surface water withdrawals depends from the regional policies developed to answer at the subsidence problems posed by the unsustainable uses of groundwater in the South East part of the region (Bologna, Ravenna and the coastal zone), using a canal (Canale Emiliano Romagnolo, CER), which can tale about 60 Cubic m. /sec from the Po River for the agricultural uses and the Ridracoli Dam builded at the end of the 80' for the civil uses and a strong regulation about dwells and groundwater withdrawals. Actually the groundwater deficit is estimated at around 25 Mcm/y, with the worst problems in Bologna and also in Parma. If we look at the surface water the estimated deficit due to the future application of he environmental flow is around 56 Mcm. The average regional consumption for domestic uses is 170 l/capita/day (l/c/d). The estimated overall (real and apparent) leakages from the civil networks are 123 Mcm./y, which means about the 26% of the civil withdrawals.

Among others, the application of River Environmental Minimum Flow Requirement is the most demanding task. The needs for realising higher volume of water to the rivers impacts the actual use of resources with particular significance during summer when the water flow is low while the water demand is at the highest level. In most of the cases, it is needed to revise 'historical" water withdrawal, that were already present in the last centuries for irrigation and old mills and in the 20ies century for drinking purposes. The level of the conflicts is therefore pretty high.

At the end of the year 2003 the regional Government approved the draft of the regional Water Protection Plan which represents the planning tool of Public Administrations (Region and other local institutions) to achieve the qualitative aims for the 2016 defined by European Directives (Water Framework Directive etc.) and Italian Laws (D.Lgs. 152/99), through an integrated approach which connects the qualitative aspects (pollution ecological aspects, biodiversity.) and the quantitative aspects. (water conservation, minimum flow etc.). The regional strategy is based on the twin track approach and considering the regional situation is firstly based on the development of new regional policies for water conservation and the demand government, not forgetting the infrastructural development where necessary (for instance the local connnections with the Canale Emiliano Romagnolo and the uses of the water for other uses then only agriculture). The conservation Program, integral part of the regional Water Protection Plan, includes also a Drought contingency Programme. The main Conservation program actions are:



As EA suggest Climate change can have an effect on:

• demand for water;
• availability of water.

In Emilia-Romagna the increase of temperature from 2000 to 2016 means a modest increase in the domestic water demand (few millions of cubic meter). The irrigation season in Regione Emilia-Romagna is the summer. The demand for irrigation water depends from a lot of factors: temperature, precipitation, wind etc. If we look at studies for north Italy and our region we can see that for summer there is a weak trend for an increase in precipitation and quite no increase in temperature. The increase in CO_2 concentration means also a more efficient use of water from the most of the agriculture plants. For these reasons, without a regional modelling of climate change, the draft Plan decided, as for the industrial demand, to suppose a neutral situation. We think anyway to stimulate at the national and regional level, an approach to the climate change similar to with studies and regional modelling, adaptation and mitigation.

On the availability of water our strategy, as the EA for a longer period assume that for the next 12 years the public systems (also for agriculture) maintain their actual supply, based on the last ten years average, which was a strongly drought period, this assumption looks like conservative. This approach is builded also on the time to revise the Planning (as in the WFD the Plan is revised every six years) and on the process of program assessments, which will be implemented with the plan implementation.

The demand scenarios without the actions are for Civil Water uses an 8% population growth, stability in the unitary consumption and a "natural" reduction of water losses from 26% to 20%. The Industry is in reduction from the 70'. For Agriculture there is still a growing irrigation surface, but a growing technological efficiency at the field with an almost stable demand (not clear indication from CAP). The most important actions will be a reduction of the water losses in the irrigation network, water saving by irrigation techniques, and the promotion of appropriate irrigation technologies and timing through advice (better water balance and advice in real time using internet) and demonstrations of best practices, supported by further research on environmental impact, to identify new technical options to address problems.

Finally, the report presented by IPCC predicts changes in the regional distribution of precipitation, leading to drought and floods, changes in the frequency of occurrence of climatic extremes, in particular in the frequency of heat waves. Climate changes that were observed during the last decades in our region seem to be consistent with these predictions and produced social impacts even at a local scale. The water regional Plan take care of those aspects in order to define, for the first time in the Regione Emilia-Romagna, a need to define a Drought contingency Program at the regional and local levels. Studies realised for the planning show as the last 15-20 years were years of growing drought, using indicators as Standard Precipitation Index (SPI) and others. Anyway this specific Risk must be afforded as in other sectors, as floods etc. with a planning strategy which shall be implemented after the Plan adoption and asking to the local actors to define within 2006 their Contingency Programs following the regional guidelines.

Future Research and Pilot Project

Discussing the draft Plan a few suggested that climate change could influence negatively the groundwater recharge. Moreover in the past, and is still in action, there is a certain recharge decrease caused from the strong urbanisation. A single research about the Taro River shows no influence in the last twenty years. In this case it is impossible to state e decreasing general trend, for the aquifers seem to be generally recharged, looking at the piezometry. However the extreme events increment could really increase the recharge, which generally happens in floods period. About these aspects the Region should finance studies and applied research, starting from the mathematical model developed by the planning. The Region should yet invest research and Pilot studies and project in the aquifer artificial recharge, specifically in the zone near to the Po River.

Conclusions

The high level of uncertainty and the not complete understanding of the climate change phenomena require the maximum flexibility on the water resource planning and management. Therefore it is necessary that the policy and the actions on the water resource management and protection be elaborated with the participation of all stakeholders. The Water Protection Plan of the Emilia-Romagna Region has an approach to water resources planning mainly based on the sustainable development and the "twin-track" strategy, and it seeks the water efficient use and the water saving and conservation. The strategy of the Regional Plan is also strong in terms of promoting prudent use of natural resources, and it promotes measures no regret, which are those whose economic rate of return justifies them regardless of future changes in climate. At last, it is also based on the integrated water resource management, which requires a combination of the supply system management, the demand management, the resource operation and the risk management.

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