Climatic scenarios and their impacts on irrigated agriculture in Emilia-Romagna, Italy

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Abstract: *We produced downscaled climatic projections (based on A1B Ipcc emission scenario) for six Italian study areas, in the framework of the Italian Agroscenari research project. The projections were analyzed in term of their impact on irrigation demand for fruit and horticultural crops in the study area of Faenza, devoted to specialized fruit cropping, and located in the Romagna sub-region, northern Italy. The climate change impacts for the period 2021-2050 on crop irrigation water needs were assessed by means of the Criteria water balance model, in the two versions available, Criteria BdP (local) and Geo (spatial) with different levels of detail. We found in general an irrigation demand increase of about +10% comparing the 2021-2050 period with the reference years 1961-1990, but no substantial differences with more recent years, i.e. 1991-2008, mainly due to a projected increase in spring precipitation compensating the projected higher summer temperature and evapotranspiration.*
Keywords: *climate change, irrigation, statistical downscaling, kiwifruit.*

Riassunto: *All'interno del progetto nazionale di ricerca Agroscenari, sono state prodotte proiezioni di cambiamento climatico (basate sullo scenario di emissione A1B dell'IPCC) per sei aree di studio italiane. Gli impatti delle proiezioni sono stati analizzati in termini di domanda irrigua per le colture orto frutticole nell'area di studio di Faenza, area vocata alla frutticoltura specializzata e localizzata in Romagna (Nord Italia).*
Gli impatti del cambiamento climatico per il periodo 2021-2050 sui fabbisogni irrigui delle colture sono stati stimati mediante il modello di bilancio idrico Criteria, nelle due versioni disponibili: Criteria Bdp (modello puntuale) e Criteria Geo (modello spazializzato) con differenti livelli di dettaglio. In generale, si è stimato un aumento della richiesta irrigua di +10% mettendo a confronto il periodo 2021-2050 con quello di riferimento 1961-1990, ma non è stata trovata una sostanziale differenza con gli anni più recenti (1991-2008), ciò è dovuto essenzialmente al previsto incremento delle precipitazioni primaverili che compensano le più alte temperature e la maggiore domanda evapotraspirativa prevista.
Parole chiave: *cambiamento climatico, irrigazione, regionalizzazione statistica, kiwi.*

INTRODUCTION

According to the IPCC 4th Assessment Report "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed anthropogenic greenhouse gas (GHG) concentration" and "continued GHG emissions at or above current rates would cause further warming" i.e global temperature increase and sea level rise.
This change would have different impacts in different planet areas such as the Northern Hemisphere, tropical and temperate regions (IPCC, 2007) but also in different sectors of human activity. More specifically agriculture, being so dependent on climate, is expected to experience with greater intensity the impacts of anthropogenic climate change, so a large number of studies have been carried out on the subject, for example on the influence of climate change on vegetal biodiversity (Thuiller, 2005), on crop yield (Parry, 2004) and on agro-meteorological variables like evapotranspiration (Harmsen, 2009) or crop water use efficiency (Wallace, 2000).
Irrigated crops produce about 40% of total agricultural output and their yields are typically twice those of rain-fed crops. In more detail, the world irrigated surface represents the 18% of total cultivated land. Moreover the agriculture is the section that mainly uses water among human activities: irrigation water withdrawals are 70% of the total (Fischer, 2007). These data show that the water is an essential resource and to know the available quantity for agriculture in the next future is strategic for a rational plan of its use.
General studies in order to evaluate climate change impacts on global water resources (Arnell, 1999) and, in more detail, on the global irrigation water demand (Döll, 2002) were carried out. Scenarios analysis in California on the projected increase of the irrigation demand and on the rising competition between irrigation and other water use were published (Purkey, 2007). Several

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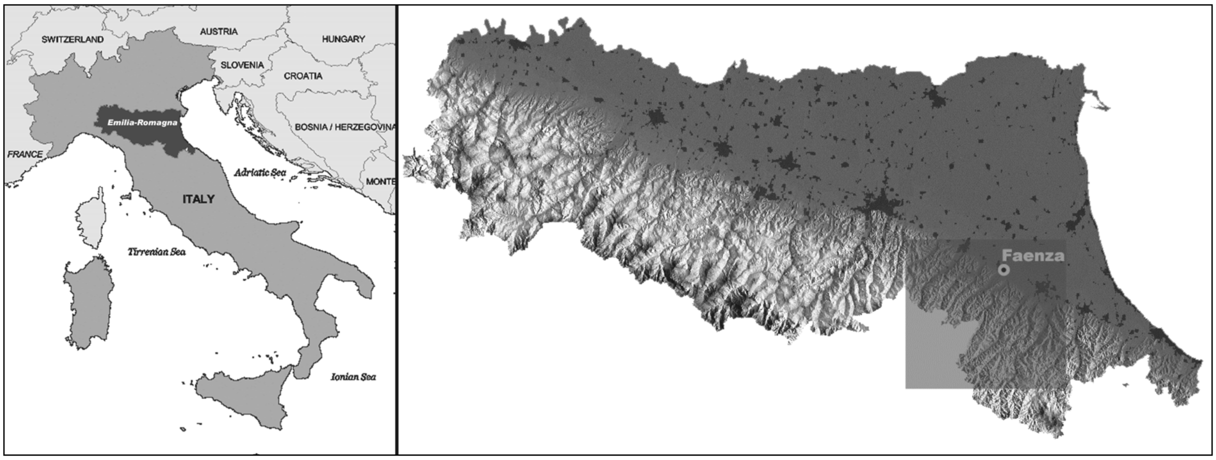

Fig. 1a - The study area.
Fig. 1a - L'area di studio.

studies and projects that evaluate the influence of climate change on irrigation at national level for countries such as Israel (Fleischer, 2007), China (Thomas, 2007) , California (Schlenker, 2007) and on limited study areas (Rodrıguez Dıaz, 2007) were developed.

From a methodological point of view, all these studies are based on climatic projections directly derived by General Circulation Models (GCM). Scientific literature lacks studies that link climate change and irrigation, applied to local study case by means of downscaled climatic scenarios, referred to the proper scale by means of dynamic or statistical techniques.

The topic of the GCMs uncertainty is debated in the scientific community and it is discussed on the IPCC AR4 (2007); in this report it is underlined that "clouds represent a significant source of potential error in climate simulations" and that "the sign of the net cloud feedback is still a matter of uncertainty, and the various models exhibit a large spread. Further uncertainties arise from precipitation processes".

The Coupled Global Climate Model (CGCMs) used in this work are produced in the framework of the Ensembles project, ended in December, 2009: this is a new generation of models compared to the IPCC-2007 models. One of the main aims of the Ensembles project was to quantify and reduce the uncertainty of these models improving their skill to represent physical, chemical, biological processes and feedback process.

In this study, carried out in the framework of the Agroscenari national project, the main aim is to compare current irrigation volumes in the Faenza study area, one of the five study areas of the Agroscenari project, with the likely irrigation under climate change conditions, referred to the 2021-2050 period. For these thirty years, multi model climatic projections downscaled on the study area are available. The comparison was carried out for the main crops of the area, with a detailed analysis for the kiwifruit vine.

MATERIALS AND METHODS

Study area

The study area is located near Faenza (Fig. 1), a city of Romagna, a geographical subregion of the Emilia-Romagna region, in northern Italy. The analysis for this study area were focused on soil water content, irrigation methods, development of crops typical of this area. The area of Faenza is characterized by highly valued horticulture, in particular by kiwifruit orchards. Kiwifruit (*Actinidia chinensis Planch.*) is a fruit tree vine characterized

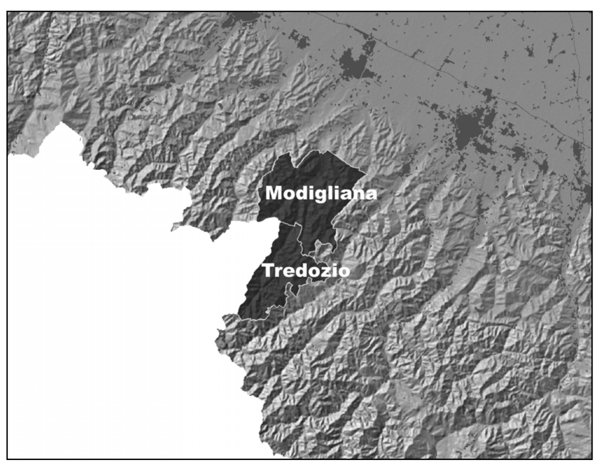

Fig. 1b - A zoom to Modigliana and Tredozio municipalities, object of the spatial analysis.
Fig. 1b - Un ingrandimento sui comuni di Modigliana e Tredozio, oggetto dell'analisi spaziale.

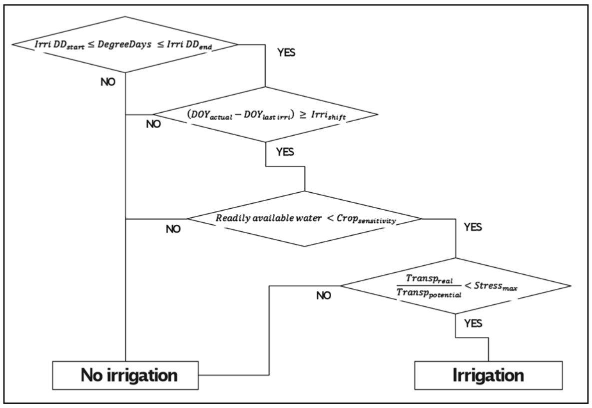

Fig. 2 - Flow chart of irrigation algorithm in Criteria (Irrigation volume= min (a, b); a = water volume needed to restore the rooted layer to field capacity; b = maximum irrigation volume).

Fig. 2 - Diagramma di flusso dell'algoritmo di irrigazione in Criteria (Volume irriguo = min (a, b); a = volume irriguo necessario a portare lo strato radicato alla capacità di campo; b = massimo volume irriguo).

by high irrigation water needs, that here is studied from the point of view of its irrigation demand.

In order to calibrate a water balance and irrigation assessment model called Criteria (see below), we used data collected from 1996 to 2008 in a farm located south of Faenza, in the Zattaglia hilly area (180 m a.s.l.).

The main crop grown in the farm is the Hayward kiwifruit variety, one of the most important and productive crop raised in Italy. The farm makes use of a drip microirrigation system controlled by tensiometers located at -30, -60 and -90 cm depth. The kiwifruit irrigation season in Romagna generally starts in May and ends in October. Precipitation and the irrigation volumes were recorded by the farm owner from April until October.

The kiwifruit orchard is grown in a clay-loam, silty clay-loam soil (35% sand, 40% silt, 25% clay) named DOG1 in the official soil map of Emilia-Romagna region (Filippi and Sbarbati, 1994).

The Criteria model

The Criteria model describes the dynamics of water in agricultural soils. The model was developed by Arpa-Simc (Marletto et al., 2007) and requires as input soil and crop parameters and daily meteorological data, namely minimum and maximum temperatures, precipitation, and, if available, water table depth.

Criteria is based on the approach of Driessen (1986) and Driessen and Konijn (1992) but was improved assuming a multilayered soil and explicitly computing approximate values of daily actual evaporation, transpiration, water flows between layers, deep drainage, runoff and subsurface runoff. In order to compute crop evapotranspiration, the Heargraves-Samani (1985) algorithm is used, because of the large diffusion of the equation and the low number of parametes needed.

Soil water flow can be described in the model either using a mono or three-dimensional numerical solution of the Richards equation (Bittelli et al., 2010) or using an empirical infiltration model, the former being more precise, though requiring a higher computational effort with respect to the latter. Crop development and the dynamics of related processes, such as the leaf area index (Lai, $m^2\,m^{-2}$) and the rooting depth (m), are simulated in Criteria by means of simple empirical equations based on degree days (°C) sums.

In order to assess the crop water demand, the irrigation process is controlled by some parameters such as the irrigation season duration, the irrigation shift minimum period, the maximum volume for a single irrigation, crop coefficients reached by the crop in the maximum development, crop sensitivity values to the water stress and, if applicable, percentage of controlled stress.

The irrigation season length is kept within fixed beginning and ending dates, but the actual irrigation period starts and stops according to a degree days sum, taking into account the weather conditions of every specific year, anticipating it in warm years and delaying it in cold ones. The model interface allows the user to choose between different irrigation methods (i.e. micro irrigation, sprinkler irrigation), to introduce time shifts and maximum volumes. Irrigation dates are computed according to the soil water content, taking into account water stress sensitivity values specific for crops and phenological phases. The value of crop sensitivity to the water stress is the readily available water percentage between the wilting point and the field capacity; below this threshold water stress would start and the model, if allowed by the user, simulates an irrigation.

By means of the controlled stress percentage, it is possible to extend the stress period up to a value physiologically tolerable by the plant. Stress percentage value is computed by means of the ratio between actual and potential transpiration.

The irrigation algorithm of Criteria can be summarized in this way (Fig. 2): the model checks if the current day of simulation is included in the irrigation season, if from the last irrigation a number of days equal to the irrigation shift is progressed and if the readily available water in the rooted zone (weighted on the basis of the root density in the

Parameter	Value
LAI max [$m^2 m^{-2}$]	3.5
Kc max [-]	1.1
Root depth [m]	1
Degree Days Thershold [°C]	5
Irrigation Degree Days start [°D]	200
Irrigation Degree Days end [°D]	3500
Irrigation shift [days]	none
Leaf tension at wilting point [hPa]	8000
Crop sensitivity [-]	0.5
Controlled stress percentage [-]	90%
Reference daily irrigation [mm]	5

Tab. 1 - Kiwifruit parameters used in Criteria calibration.
Tab. 1 - Parametri del kiwi utilizzati per la calibrazione di Criteria.

different layers of soil) is minor than the crop sensitivity value to the water stress. If all these conditions are true, irrigation could be necessary for the plant, so, if requested, a check about the controlled stress percentage of the previous day is computed.
If all the previous conditions are true, an irrigation volume is distributed. This is computed as the minimum between the predefined irrigation volume and the water volume needed to restore the rooted zone to the field capacity. This computational choice is applied in order to avoid excessive irrigations that would be converted in run-off losses. The irrigation volume is considered seeped only in the rooted layer, so an irrigation without losses is computed.

Criteria calibration and validation on kiwifruit in the Faenza area

Arpa-Simc carried out a simulation about kiwifruit irrigation needs for the period 1996 – 2008, by means of the water balance model Criteria. For the calibration, the model was feed by precipitation and daily temperatures from station data. These data series allowed the model calibration for the crop and irrigation parameters; for the main parameters the optimal values obtained are shown in Tab. 1.
Fig. 3 shows the comparison between the yearly cumulated irrigations estimated by the model and the actual irrigations; the series are well correlated with a determination coefficient R^2 equal to 0.86.
Fig. 4 and Fig. 5 show the same comparison between the monthly cumulated irrigations, with a high correlation (R^2= 0.93) and an efficiency index (EI) equal to 0.67. These results show that Criteria model is able to simulate the kiwifruit irrigation water need with a high accuracy level: the model explains the 90% of the real variability. This is true also for the data distribution, in particular for the monthly cumulated real irrigations that show a maximum value of 123.3 mm and an average of 46.1 mm, the model evaluates as maximum value of 125 mm and an average of 46.5 mm.

Operational scheme and climate change impact analysis on crop irrigation water needs

Fig. 6 shows the computational scheme developed at Arpa-Simc for climate change projections downscaling and for agronomical impact projections. This scheme was devised within the European ENSEMBLES

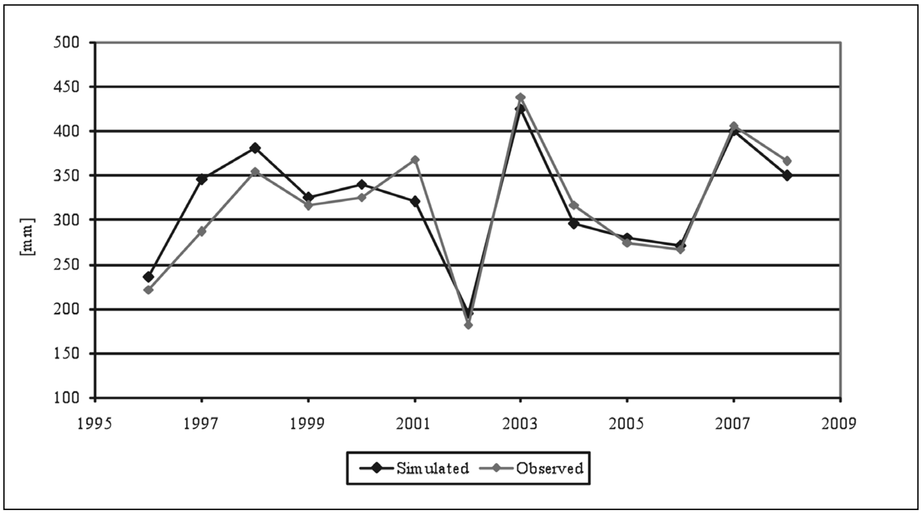

Fig. 3 - Comparison between yearly irrigation observed and simulated by Criteria (R^2= 0.86).
Fig. 3 - Confronto tra le irrigazioni annuali osservate e simulate da Criteria (R^2= 0.86).

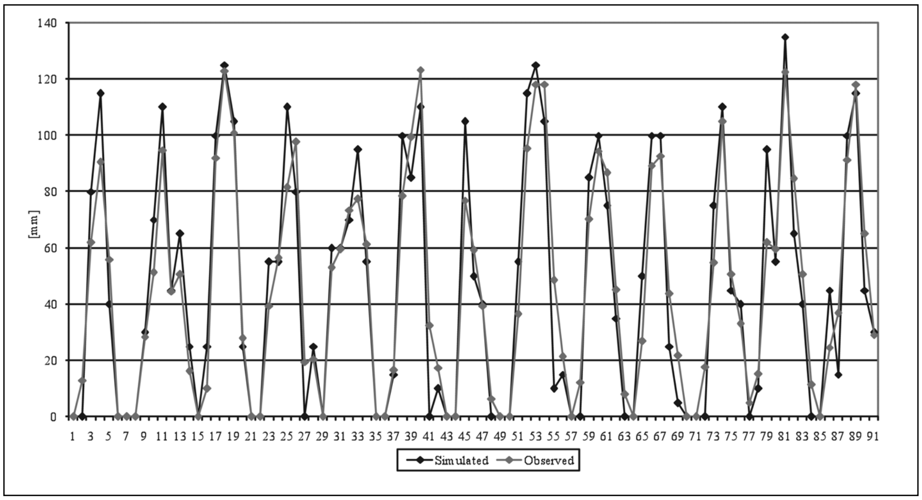

Fig. 4 - Comparison between cumulated monthly irrigation observed and simulated by Criteria (R^2= 0.9).
Fig. 4 - Confronto tra le irrigazioni cumulate mensili osservate e simulate da Criteria (R^2= 0.9).

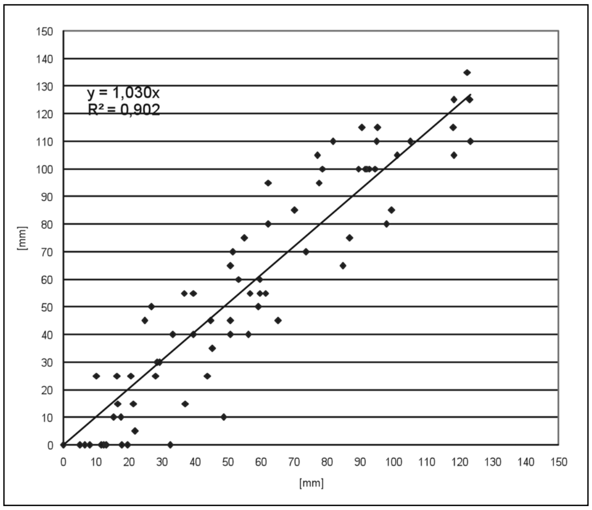

Fig. 5 - Correlation between the monthly cumulated irrigations observed and the irrigations simulated by Criteria.
Fig. 5 - Correlazione tra le irrigazioni mensili cumulate osservate e le irrigazioni simulate da Criteria.

project (Tomei et al., 2009) and it is used also in the Italian Agroscenari project (Tomozeiu et al., 2010; Villani et al., 2010).
The structure of the operational chain is the following: the soil water balance and crop development model Criteria (Marletto et al., 2007) requires as input daily meteorological data, namely temperature, precipitation and, if available, hypodermic groundwater depth. Meteorological daily data, referred to a future projection, are synthetically produced with a weather generator (WG) using as input predicted seasonal anomalies added to the local climatology. These anomalies are obtained by means of a statistical downscaling technique applied to the general circulation models simulations. The synthetic weather data produced by the WG can also be used to assess the hypodermic groundwater level using an empirical equation developed by Arpa-Simc (Tomei et al., 2010).

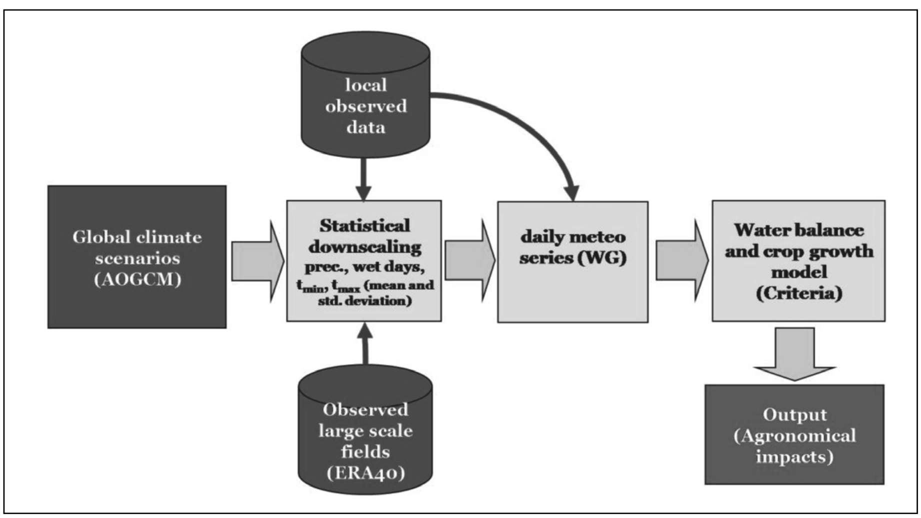

Fig. 6 - Operative scheme for agronomical forecasts.
Fig. 6 - Schema operativo per le previsioni agronomiche.

AOGCM	INSTITUTION	Atmosphere (AGCM)	Resolution1	Ocean (OGCM)/Resolution2
INGV-SINTERX-G	INGV-Italy	ECHAM4 (T106L19)	T106	OPA8.2/0.5-2°
EGMAM (run1; run2)	Freie Universitaet Berlin (Germany)	ECHAM4 (T30L39)	T30	HOPE-G/0.5-2.8°
METO-HC-HADGEM1	Met Office Hadley Centre (UK)	HadAM3 HadGAM1	2.5°x3.75°	HadGOM1/0.33-1
IPSL-CM4	Inst. Pierre Somon Laplace (France)	LMDZ-4	2.5°x3.75°	OPA8.2/0.5-2°
ECHAM5-MPI-OM	Max-Plank Institute (Germany)	ECHAM5.2.02	T63	MPI-OM /1.5°

Tab. 2 - Climatic global models used for the climate change scenarios.
Tab. 2 - Modelli climatici globali usati per gli scenari di cambiamento climatico.

By means of Criteria Geo, the geographical version of Criteria model, a further spatial analysis about the irrigation water needs in the area for the period 1961-1990 and 2021-2050 is carried out.
The distribution of the crops in the area is based on the land use map of 2008 for Modigliana and Tredozio (Fig. 1b), municipalities that are included in the 1362 CRA-CMA cell. This thematic map is derived from the PAL-Lamone project (Spisni A., 2009).

The crops in the area are classified as:
– summer herbaceous crops, simulated in Criteria as two cycle of horticultural crop from April to September;
– orchards, simulated as peaches trees;
– multiannual herbaceous crops, simulated as alfalfa;
– autumn herbaceous crops, simulated as wheat;
– vineyard;
– kiwifruit.

Climate change scenarios

In the framework of the National project Agroscenari, Arpa-Simc produced climate change scenarios of temperatures (minimum and maximum) and precipitation for years 2021-2050 from the Agricultural Research Council (CRA – CMA) dataset computed on a national grid of 30 km; one of these cells is located in the Faenza area and it is identified as cell 1362.
The emission scenario considered in this study is the A1B (a balanced emphasis on all energy sources) from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) (Nakic´enovic´ et al., 2000).
The climate change scenarios of temperature and precipitation at local scale for the 2021-2050 period used in this study are produced by means of the statistical downscaling (DS) technique applied to the output (predictors) from AOGCM (atmosphere-ocean coupled general circulation models) derived by ENSEMBLES project (Van der Linden, 2009).
The DS technique is based on the identification of a statistical relation between the large scale field (predictors) and the local scale field (predictands).
The uncertainty reduction/quantification in the DS technique has been deal in the set-up phase of the DS model, using different predictors (single or combined), defined on different areas and different time periods (Tomozeiu et. al 2007). The predictors projections (i.e. for the period 2021-2050) derived from the GCM-ENSEMBLES are applied to the selected DS scheme, in order to obtain the local scale signal.
By means of a multivariate regression, based on the Canonical Correlation (CCA) technique (Von Storch, 1995, Zorita and Von Storch, 1999) applied to the filtered predictors-predictands fields, the large scale patterns that are better correlated to the local scale patters (CRA-CMA in this work) are identified.
The set-up of the model has been carried out by using as large scale fields the best predictors in the DS scheme deducted from the fields of temperature at 850 hPa (T850), geopotential height at 500 hPa (Z500), mean sea level pressure (MSLP), derived from ERA40 reanalysis for the 1958-2002

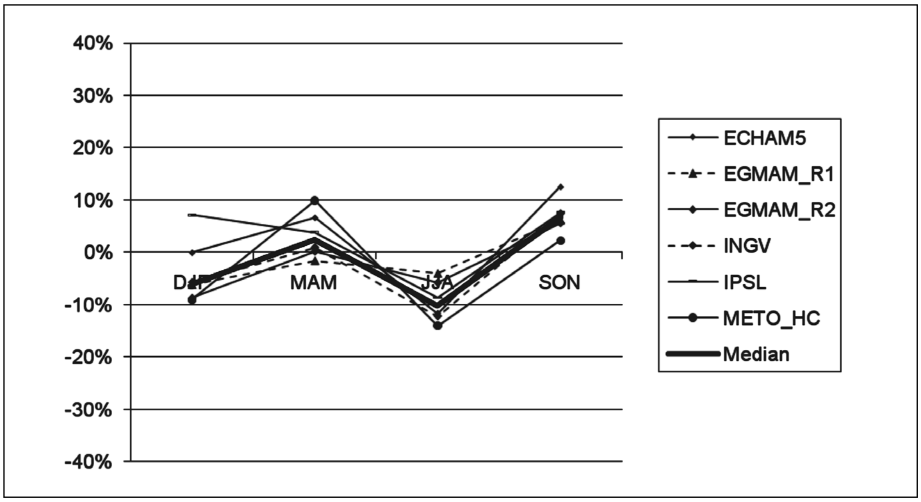

Fig. 7 - Seasonal anomalies in precipitation (%) under scenario condition in the study area of the 2021-2050 period with respect to reference period 1961-1990.
Fig. 7 - Anomalie stagionali di precipitazione (%) in scenario di cambiamento climatico nell'area di studio per il periodo 2021-2050 rispetto al trentennio di riferimento 1961-1990.

period. These fields are well represented by the global models (Anagnostopoulou et al., 2006; Johns et al. 2003, Giorgi et al., 2004; Tomozeiu et al., 2007).
The AOGCM used in the present work are provided by the following groups (Tab. 2): MPIMET (ECHAM5 model), FUB (EGMAM models with 2 runs), METO-HC (METOHC models), INGV-CMCC (SINTEX-G model) and IPSL Global Climate Modeling Group (IPSL model).
This technique allows to assess the coupled structure between large scale fields, that are more reasonably predictable by the AOGCM models, and the local scale fields (minimum and maximum temperatures, precipitations, frequency of wet days) in order to maximize the correlation between the temporal series.
These seasonal climatic projections have been used as input data for a weather generator (WG) in order to produce daily synthetic series (Tomei et al., 2009) of precipitation and temperature related to the local climate.
WG used in this study is based on Richardson et al. (1984), modified by Campbell and Stöckle (1999). The aim is to generate daily weather data for temperature (minimum and maximum) and total precipitation from monthly climatic statistics of seven input variables: mean of maximum temperature, mean of minimum temperature, standard deviation of maximum temperature, standard deviation of minimum temperature, mean of total precipitation, fraction of wet days, difference between maximum temperatures on dry and wet days.
The difference in temperature between dry and wet days is a critical variable in order to couple temperature and precipitation, that otherwise would be uncorrelated. Days are considered wet only if the precipitation is higher than 0.2 mm, in order to remove bias due to dew deposition. For a climatic

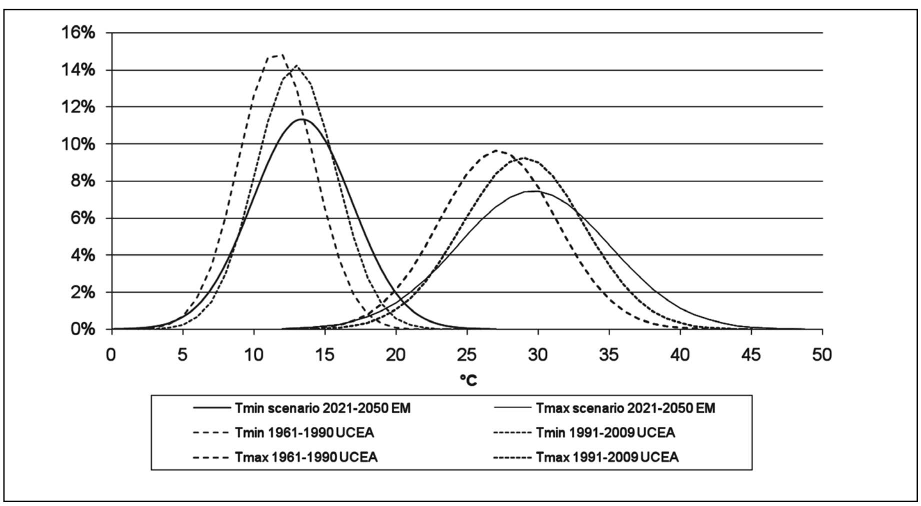

Fig. 8 - Comparison between the minimum and maximum temperatures distribution of the 2021-2050 period with respect to reference period 1961-1990, JJA season.
Fig. 8 - Confronto tra le distribuzioni delle temperature minime e massime per il periodo 2021-2050 rispetto al trentennio di riferimento 1961-1990, stagione JJA.

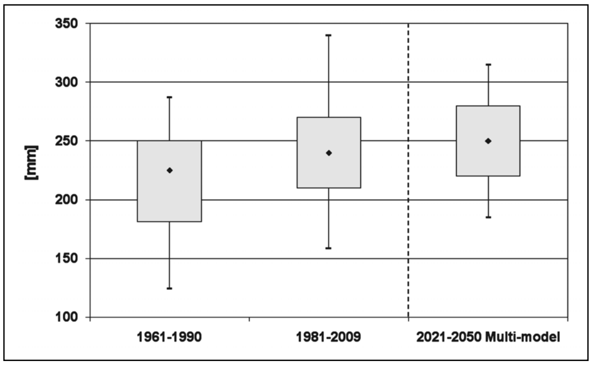

Fig. 9 - Kiwifruit water need distribution in the Faenza study area simulated by Criteria model, for the periods 1961-1990, 1981-2009 and 2021-2050 (A1B scenario). The box represents the data included between the 25th and 75th percentiles, the diamond is the median and the whiskers are the 5th and 95th percentiles.
Fig. 9 - Distribuzione del fabbisogno irriguo del kiwi nell'area di studio di Faenza simulata dal modello Criteria, per i periodi 1961-1990, 1981-2009 e 2021-2050 (scenario A1B). I box rappresentano i dati compresi the il 25° e il 75° percentile, il rombo rappresenta la mediana e i whisker sono il 5° e 95° percentile.

statistic, input data must be averaged on a significant period (30 years at least).
For the six AOGCMs 50 WG runs are produced, it means that for this study 300 years of data are produced. It is clear that the time series doesn't have statistical relevance, each of that year is a sample equally probable representative of the A1B scenario for the 2021-2050 period.

RESULTS

Analysis of the climate change projections in the Faenza area

Fig. 7 shows the seasonal climate change projections in total precipitation for the study area of Faenza (1362 CRA-CMA cell) for the four seasons considered here (DJF, MAM, JJA, SON), as results from the statistical downscaling applied to the output of five AOGCMs (gray lines). The Ensemble mean is also represented in Fig. 7 (black line).
As could be noted, all the models show a decrease in winter and summer precipitation, for the period

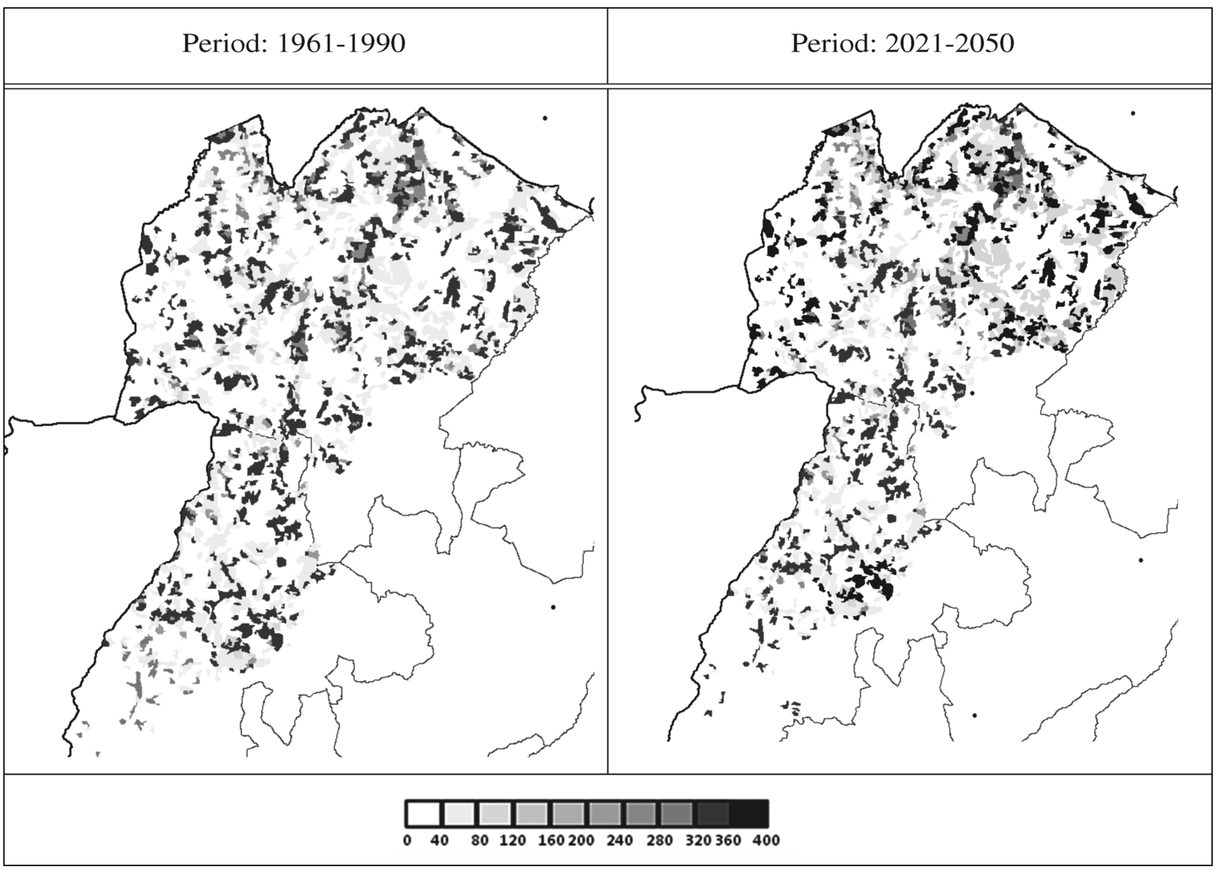

Fig. 10 - Irrigation water need simulation (mm) for the crops on the agricultural land use map of the 2008 for Modigliana and Tredozio municipalities.
Fig. 10 - Simulazione dei fabbisogni irrigui (mm) per le colture rilevate dalla mappa di uso del suolo del 2008 per i comuni di Modigliana e di Tredozio .

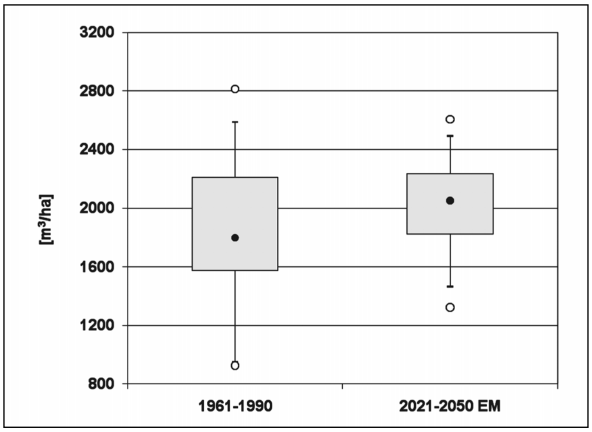

Fig. 11 - Average water need distribution comparison for 1961-1990 and 2021-2050 periods on the basis of 2008 agricultural land use map.
Fig. 11 - Confronto tra la distribuzione del fabbisogno irriguo medio dell'area per i periodi 1961-1990 e 2021-2050 sulla base della mappa di uso del suolo agricolo del 2008.

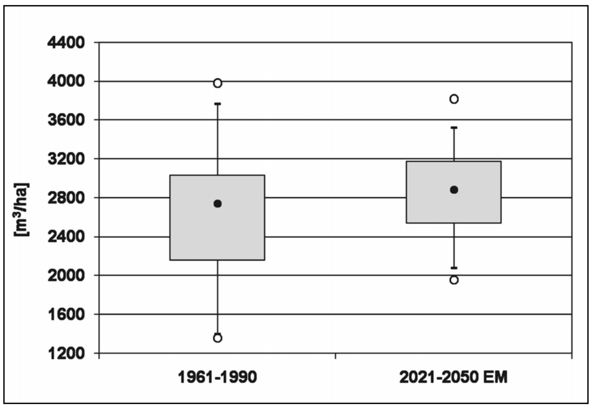

Fig. 12 - Kiwifruit water need distribution comparison for 1961-1990 and 2021-2050 periods on the basis of the 2008 agricultural land use map.
Fig. 12 - Confronto tra la distribuzione del fabbisogno irriguo del kiwi dell'area per i periodi 1961-1990 e 2021-2050 sulla base della mappa di uso del suolo agricolo del 2008.

2021-2050 with respect to 1961-1990. This decrease is around 10% in winter and similar values are detected in summer. Spring shows a slight increase, otherwise in autumn a more intense increase (about +10%) is projected.
As concerns the temperature (Fig. 8), the projections show that increases could be expected to occur under scenario conditions for all seasons, overall for JJA, in both minimum and maximum values. The magnitude of change in JJA season is 2.5°C for maximum temperature and 1.8°C for minimum temperature. The Fig. 8 shows also that CRA-CMA data referred to the last period (1991-2009) are close to the values projected by the models.

Local analysis of kiwifruit irrigation water need in the Faenza area

Kiwifruit irrigation water needs were estimated by means of Criteria model, in the study area of Faenza for the period 1961-2009 with local data from CRA-CMA analysis and for the period 2021-2050 with climate change projections as described above (Fig. 9). CRA-CMA analysis data were divided into two periods partially overlapped: the reference climate period (1961-1990) and the last available 29-year period (1981-2009). Fig. 9 shows the irrigation water need distribution during the three periods analyzed. For the 2021-2050 period with respect to the 1961-1990 period, a general increase of more than 10% is projected with a more intense increase for the 5th percentile. The comparison between the last observed period (1981-2009) and the projections shows a slight increase of the crop water demand with the exceptions of the 95th percentiles that shows a decrease. It is important to consider the difference in the number of samples of the two distributions: the observed data are composed by a maximum of 30 samples whereas the projections are composed by 300 samples, this is the probable reason of the lower variability of the distribution under scenario condition.

Spatial analysis of the irrigation water need of the crops in the Faenza area

The results of spatial analysis on the irrigation water need for the crop in the area are presented. The maps in Fig. 10 show that for all the areas, with the exception of these covered by autumn herbaceous crops that are rain fed, in the period 2021-2050, the irrigation water need is projected to increase of about 10% with respect to 1961-1990 for each range of the classification.
This projection can be detailed by the next three graphs: Fig. 11 represents the box and whiskers distribution of irrigation water need averaged for all the crops, Fig. 12 shows the irrigation water need for the kiwifruit and Fig. 13 for the summer herbaceous crops. All the figures show the comparison between 1961-1990 and 2021-2050 periods.
For all the three cases, the trend in the values distribution is similar: in the projection period the values of minimum and 5th percentile increase of about +40% with respect to the reference period, the 25th percentile and the median increase of

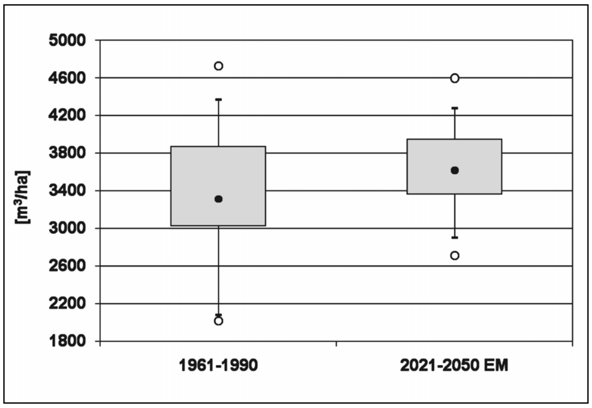

Fig. 13 - Summer horticultural crop water need distribution comparison for 1961-1990 and 2021-2050 periods on the basis of the 2008 agricultural land use map.
Fig. 13 - Confronto tra la distribuzione del fabbisogno irriguo delle colture estive erbacee dell'area per i periodi 1961-1990 e 2021-2050 sulla base della mappa di uso del suolo agricolo del 2008.

about +10%, the 75th percentile is stable and the higher values (95th percentile and the maximum value) slightly decrease or are stable.
This increase is clearly connected with the projected increment in temperatures and with the consequent increase in evapotranspiration demand. The projected slight decrease of summer precipitation in the study area causes a further increase of this phenomenon for crops with growth cycle in spring and summer such as kiwifruit and summer herbaceous crops; these two projections explain the increase in the lower percentiles and median values of the distribution but an intense change in the average irrigation volume is not expected to occur because the increment of spring precipitations in the area partially compensates the two phenomena described above.
The increment of spring precipitation produces two compensative effects: the first is decrease in the irrigation water need for the crops with spring growth cycle, the second one is and a storage effect in soils at the beginning of the summer season. Therefore a higher frequency of years with a high irrigation demand is projected instead of a general dramatic increase of irrigation demand.

CONCLUSIONS

By means of Criteria model and the climate change projections properly downscaled it is possible to study the possible future evolution of irrigation in the Faenza area (Emilia-Romagna, Italy). The model was calibrated on observed data, then used to compute the irrigation water demand for the crops in the area for the reference period (1961-1990) and for the future (2021-2050). The work was carried out both on local (station) and geographically extended approaches.
The results show that, notwithstanding the projected increase in temperatures and the consequent increase in evapotranspiration demand, an intense change in the average irrigation volume is not expected to occur, because of the projected spring precipitation increase. Anyway in the future a higher frequency of years with higher than average irrigation demand can be expected. Further studies are needed to test the projections for other effects such as direct effect of increased CO_2 concentration, varying air humidity and so on.

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