Irri4web: crop water needs definition by webGIS

Fabio Zottele[1*], *Giambattista Toller*[1], *Emanuele Eccel*[2]

Abstract: *A Decision Support System for irrigation scheduling is proposed as a tool for improving agriculture sustainability and adaptations to the ongoing climatic change. In the Italian province of Trento (Trentino-South Tyrol), the newly implemented Public Waters General Exploitation Plan fixes new ceilings to the use of irrigation water and aims at its optimisation by setting up limits to soil moisture. The system was implemented for the pilot area of "Val di Non", 192 km² almost completely devoted to apple growing. The protocol entails the assessment of water content in a soil parcel, given its location and the history of the latest irrigation actions. The water balance is carried out with rainfall and temperature values spatially interpolated from the neighbouring meteorological stations. Hargreaves' equation is used for the calculation of evapotranspiration, and pedologic information is inferred by a "(pedo-) landscape map" compiled for this purpose. An estimate of soil water content is provided to end users. The spatial interpolation of rainfall and temperature is carried out either by inverse-distance (squared) weighted mean (IDW) or kriging; both algorithms duly take into account elevation. Soil water content is calculated from 7 days before to 3 days after user's request. Weather forecasts are provided by the local weather service. The system is presently ready for its distribution to farmers and agricultural syndicates.*
Key-words: *spatial interpolation, soil water balance model, irrigation scheduling, soil water need forecasting*

Riassunto: *Nell'ambito della ricerca di azioni favorevoli alla sostenibilità delle attività agricole, ivi compreso l'adattamento al cambiamento climatico in atto, si propone un Sistema di Supporto alle Decisioni per la gestione della risorsa irrigua in Trentino. In questa regione è richiesto l'adeguamento al Piano Generale di Utilizzo delle Acque Pubbliche, che fissa nuovi tetti all'uso della risorsa irrigua e favorisce i mezzi per quantificare il bilancio irriguo nei suoli. Per l'area pilota della Val di Non, 192 km² coltivati quasi esclusivamente a melo, è stato implementato un sistema che consente di stimare il contenuto d'acqua in un suolo nota la sua ubicazione e gli interventi irrigui più recenti. Applicando il calcolo dell'evapotraspirazione di Hargreaves, condotto con soli valori spazializzati di temperatura, e con indicazioni pedologiche derivanti dalla redazione di una "carta dei pedopaesaggi", dopo aver spazializzato le precipitazioni misurate dalle stazioni presenti nell'area viene effettuato un bilancio idrico e fornito un suggerimento sull'irrigazione. La spazializzazione di precipitazioni e temperatura viene condotta con medie pesate secondo l'inverso della distanza al quadrato (IDW) o kriging; entrambi gli algoritmi tengono debitamente conto della quota. Il contenuto d'acqua nel terreno viene calcolato a partire dal 7° giorno precedente alla richiesta dell'utente; la previsione viene estesa ai 3 giorni successivi utilizzando i dati forniti dal servizio meteorologico provinciale. Il metodo è attualmente pronto per essere implementato per l'utenza agricola, che potrà essere singola o rappresentata dai numerosi consorzi irrigui presenti in Trentino.*
Parole chiave: *interpolazione spaziale, bilancio idrico del terreno, gestione irrigua, previsione dei fabbisogni irrigui*

INTRODUCTION

Sustainable agriculture relies on the implementation of strict standards for the safeguard of water resources. At present, any discussion on the interaction of plants with their physical environment has to take into account the climate-driven water shortages envisaged by IPCC (2007). For southern Europe, climate projections highlight a remarkable decrease in summer rainfall, accompanied by a thermal increase (Giorgi *et al.*, 2004); thus, diminished water availability in soils during the growing season is expected. The impacts of climate change on agriculture are diverse (Rounsevell *et al.*, 2005; Grünberg *et al.*, 2007; FAO, 2007), not necessarily detrimental all over the world and/or for every crop (Olesen and Bindi, 2002; Ewerth *et al.*, 2004). The general issues at the planetary scale are often better addressed with adaptation approaches at the local scale.

In the Italian province of Trento (Trentino), the Public Waters General Exploitation Plan (PGUAP) regulates these issues since 2006 (Fezzi, 2007). Presently, the overall water requirements for irrigation are of 40.3 $m^3\ s^{-1}$ (calculated as the sum of authorization regulations). PGUAP estimates an average actual need of 21.1 $m^3\ s^{-1}$ and, in the most stressful summer conditions, fixes an average need of 0.81 $l\ s^{-1}\ ha^{-1}$. Because such conditions take place for limited time spans, the average need assessed is lower, i.e. 0.50 $l\ s^{-1}\ ha^{-1}$. Therefore, an effort is required for the rationalization of the use of the water resource, fostering the optimisation of irrigation management.

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id	Name	Latitude	Longitude	Elevation
31	Cles	46d21'40.219"N	11d2'23.852"E	652
33	Ton	46d15'38.059"N	11d4'26.143"E	448
35	Spormaggiore	46d13'15.750"N	11d2'46.021"E	548
38	Nanno	46d19'12.152"N	11d2'43.875"E	567
39	Banco-Casez	46d22'45.723"N	11d4'40.881"E	703
40	Segno	46d18'17.332"N	11d4'33.469"E	525
41	Revò	46d23'34.989"N	11d3'56.958"E	715
42	Cis	46d23'51.237"N	11d0'8.531"E	708
43	Arsio	46d25'33.073"N	11d5'47.824"E	797
45	Mezzocorona Novali	46d12'32.499"N	11d6'35.561"E	216
57	Rovere della Luna	46d14'55.154"N	11d11'7.982"E	208
58	Mezzolombardo	46d11'14.194"N	11d6'15.955"E	204
84	Fondo	46d26'15.714"N	11d7'46.713"E	907

Tab. 1 - Agro-meteorological stations used in spatial interpolation. Datum is Gauss Boaga-Rome40-West Fuse, elevation in m a.s.l.
Tab. 1 - Descrizione delle stazioni meteorologiche utilizzate per lo studio. Coordinate planimetriche in Gauss Boaga su Roma 40 fuso Ovest, quote in metri sul livello del mare.

In Trentino, irrigation covers 12% of the whole area exploitable for agriculture (SAU) – 18662 out of 135000 ha - including the total of apple and grapevine areas, and only marginally pastures and meadows (81% of the total SAU). The high standards in viticulture and apple growing must be supported by irrigation practices that consider both crop yield and quality. Moreover, the PGUAP explicitly aims at the optimisation of water use by setting up measurements of soil moisture that can be either "direct" or "indirect", delegating the monitoring of these characteristics to local farmers syndicates. Consequently, the Plan commits the regional administration to support water balance applications in irrigated soils.
In order to obtain a correct water balance it is of foremost importance to avail of accurate estimates of inputs (precipitation) and outputs (evapotranspiration) for the balance of soil water content. Since 1990, Istituto Agrario San Michele all'Adige (IASMA) has joined the AgriVideoTel project and is actively involved in the research and development of water management systems (Toller *et al*., 2002).The high costs involved with the expansion of the existing agrometeorological network made it preferable to obtain rain and evapotranspiration data by spatial interpolation. For this purpose, Eccel *et al*. (2004) developed the prototype of a client-side application (IrriGRASS) specifically bound to GRASS GIS. The IrriGRASS system implemented a water balance model on a daily scale: potential evapotranspiration was calculated with the Hargreaves' equation (Battista *et al.*, 1994), soil properties were inferred analysing soil cores. Rain and temperature inputs for the calculation of the potential evapotranspiration were interpolated by an inverse distance weighted algorithm (IDW) (Shepard, 1968). Unfortunately the IrriGRASS application soon became unmantained owing to the lack of feedback from users, who were required to install GRASS only on LINUX clients, collect huge input (Digital Elevation Model at 1 meter resolution), and establish a dedicated account to the meteorological database of Istituto Agrario. These non-trivial tasks were showstoppers for a user-friendly application.
During the last two decades, we found different approaches to the development of decision support systems for irrigation (DSS). For example *IRRINET* (Mannini, 2009) is an advisory service for the "Consorzio di Bonifica di secondo grado per il Canale Emiliano Romagnolo". It uses a large scale resolution (6.25 km^2) for the calculation of crop water requirements and it is developed using proprietary technology. Bonamano *et al*. (2008) developed *IrriWeb* based on the soil and the meteorological databases of Veneto (Italy). The system offers many choices and options to the final user, but the spatial interpolation of past and forecasted temperature and rain are not implemented. Recently, the *AQUATER* project (Acutis *et al.*, 2010) aims to model crop water availability by remote sensing image processing, geostatistical analyses and simulation models. When this DSS the will be complete, it will work on a weekly temporal resolution and will focus on risk of over/under irrigation.
This work describes **irri4web**: an advanced version of *IrriGRASS* that sets up a simplified, high

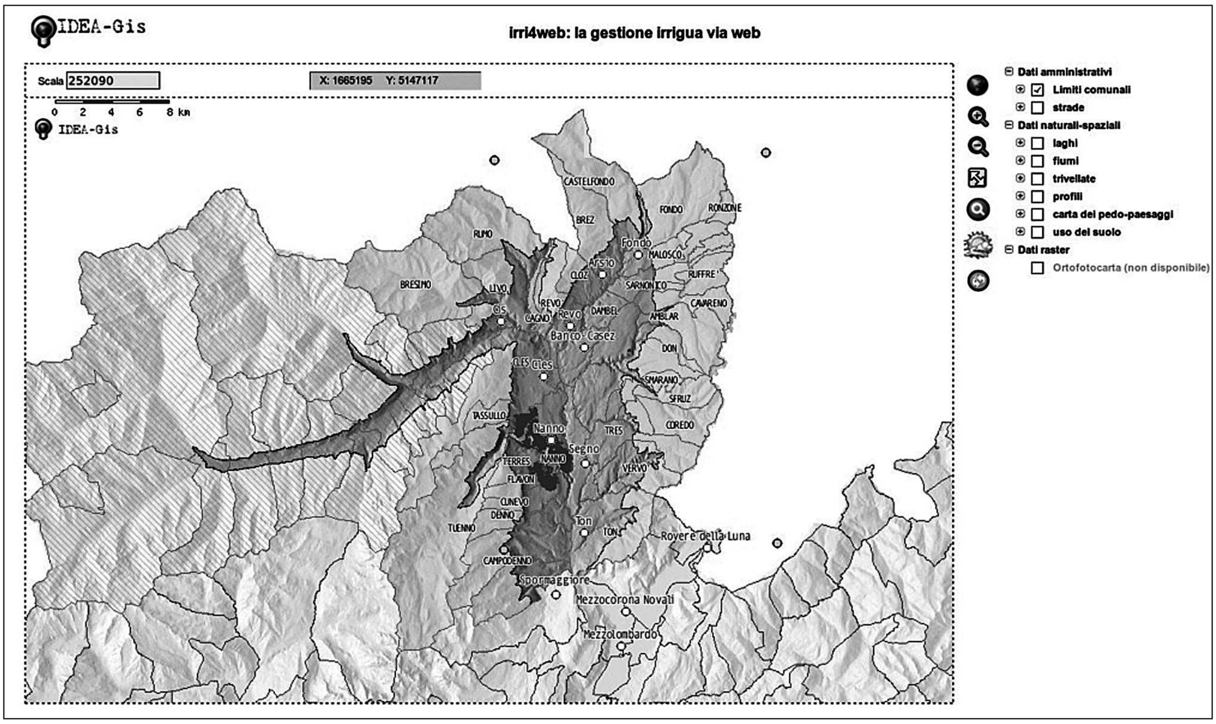


Fig. 1 - Irri4web, consulting mode: the pilot area is shown. Datum: Gauss Boaga-Rome40-West Fuse. Both agrometeorological stations (white circles) and four ECMWF meteorological model grid points for rain forecast (grey circles) are shown.
Fig. 1 - Irri4web in modalità di consultazione. È visualizzata l'area pilota (datum: Gauss-Boaga su Roma 40 fuso Ovest). Con i cerchi bianchi sono visualizzate le stazioni agrometeorologiche, in grigio i 4 punti della griglia del modello meteorologico ECMWF utilizzati per la previsione della pioggia.

resolution water balance model by spatial interpolation procedures, and integrates it in a server-side fully open source webGIS with forecasting capabilities. This DSS guides the final user through the choice process of a correct irrigation regime with a daily temporal scale, on-the-fly spatial interpolation of meteorological data and with an integration of meteorological forecasts for better irrigation scheduling. The centralized data management, achieved by open source software and spatially-enabled database systems, plays an important role in the performance, the reliability and the scalability of the entire project.

MATERIALS AND METHODS

Pilot area

For the development of an application prototype, only "Val di Non", Trentino region, Northern Italy, was investigated. A high-resolution pedologic survey was available for this area, which is the most productive zone for apple growing - one of the most notable in Europe - thanks to its good exposure and ventilation. As Val di Non is a very valuable and productive agricultural area with a complex morphology, a high number of meteorological stations has been established here (Tab. 1). Apple tree is the main irrigated crop. It is grown up to 1000 m of altitude, so the study area was further filtered out above this limit using a Digital Elevation Model with 20 meter nominal resolution (DTM) (PAT, 2006), as shown in figure 1. The main characteristics of the landscape are reported in Tab. 2. The climate of the area is temperate, oceanic, tending to continentality in the inner areas (Colombo *et al., 2001*), and "humid" after De Martonne's classifications. Mean yearly temperatures vary between 8 - 11 °C, with summer values (from May to August) between 17 and 19 °C on average. The vertical lapse rate at the ground is between –0.0045 °C

Pilot area characterization	
Area	192 km^2
Min elevation	253 m
Mean elevation	704 m
Max elevation	1000 m
Apple growing area	5876 ha
Grapevine growing area	16 ha
Non-irrigated areas	1289 ha

Tab. 2 - Characterization of pilot area.
Tab. 2 - Caratterizzazione dell'area di studio.

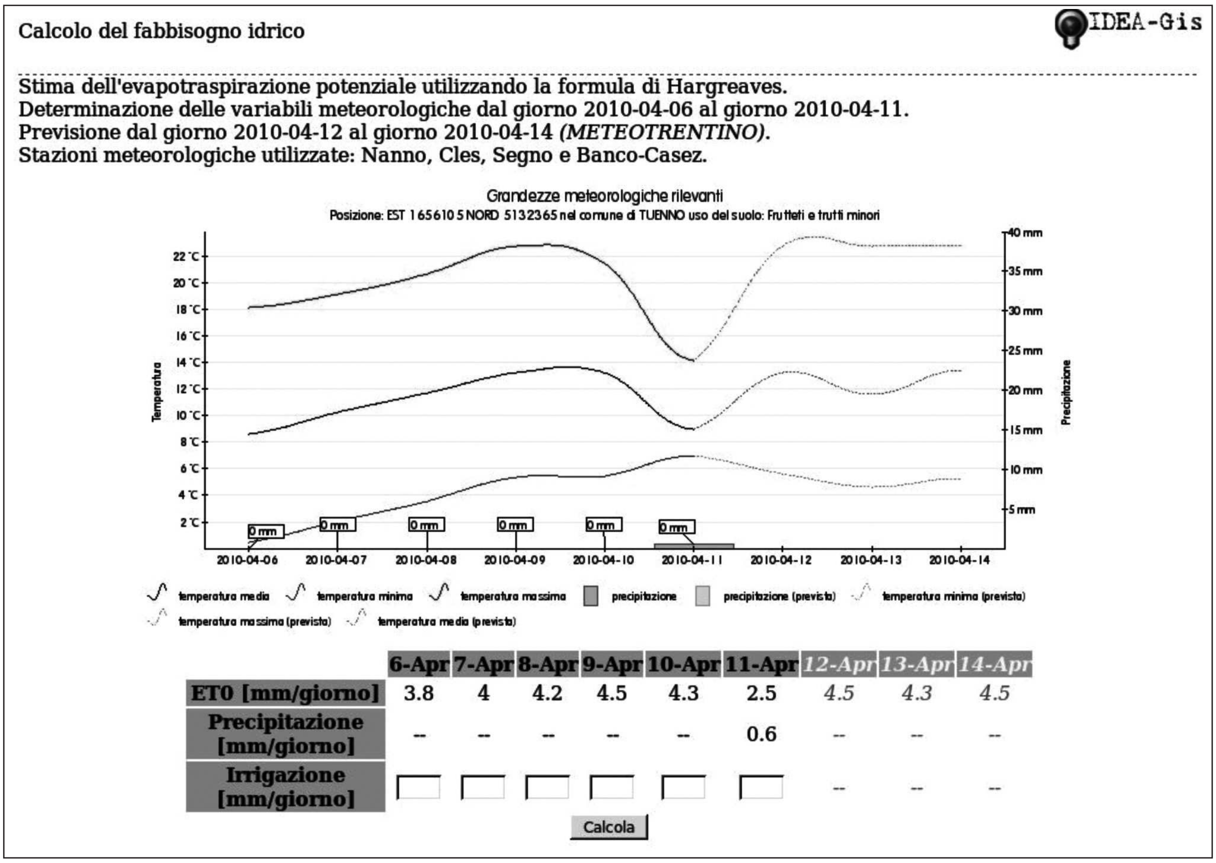


Fig. 2 - Irri4web, processing mode. Graph: spatially interpolated meteorological data for calculation of evapotranspiration; lower part: input form of the irrigation amounts during the previous seven days. Dotted curves show forecasts till day +3.
Fig. 2. Irri4web in modalità elaborativa: interpolazione spaziale delle grandezze meteorologiche necessarie al calcolo dell'evapotraspirazione (grafico) e form di immissione degli apporti irrigui durante la settimana precedente alla richiesta dei dati. Le curve tratteggiate mostrano le previsioni per i tre giorni successivi.

m^{-1} and –0.0066 °C m^{-1}, in winter and in summer, respectively. Mean annual rainfall amount ranges between 800 and 1000 mm, according to locations, with a dry winter season, a more humid one between spring and autumn and no real dry period in the summer. However, the moderate rainfall, mostly favourable sun exposure, and constant summer breeze, make Val di Non agriculture strongly dependent on irrigation that, as a matter of fact, is a widespread practice managed by growers' syndicates.

Soil survey

Because a soil map for the Trentino region was missing, firstly a (pedo-)landscape map (CPp) focusing on morphology and soil characteristics was created by visual interpretation of aerial images taken in 2003. Secondly, a soil survey was conducted, in which 908 soil samples were collected and tested for their chemical and physical properties. Bulk density, organic matter and pedotransfer functions (PTF) were also determined for further inclusion in a map focused on pedologic description of soils. The soil survey is still under progress (Sartori *et al.*, 2010).

Water balance

The algebraic sum of water inputs and outputs expressed as rain (R), irrigation (I_r), percolation (P_p) and effective evapotranspiration (ET_a) returns the water budget for a soil unit at the given day (t):

$$W^t = W^{t-1} + P^{t-1} + I_r^{\,t-1} - ET_a^{\,t-1} \pm P_p^{\,t}$$

The calculation of soil water balance is based on the hypothesis that $W^0=0.75f_c$, where f_c represents field soil capacity. $ET_a=k_{cd}ET_0$, where k_{cd} stands for a crop-specific coefficient and ET_0 stands for potential evapotranspiration.
For the calculation of ET_0 the Hargreaves' equation was applied (Battista *et al.*, 1994).

$$ET_0 = 0.0023\frac{Rg_0}{L}(T_{dm}+17.8)(T_{\max}-T_{\min})^{0.5}$$

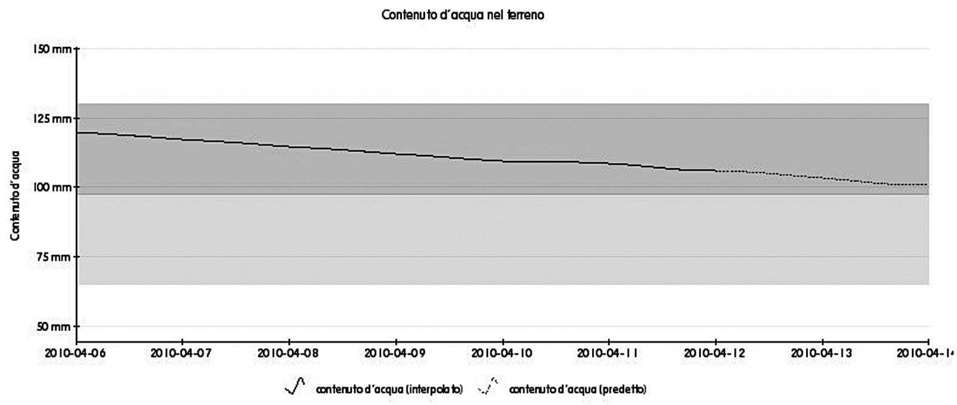
	Number of signif. days	Percentage	R^2_{min}	R^2_{max}
T_{dm}	2162 (1646)	84 (97)	0.3148 (0.3333)	0.9969 (0.9952)
T_{min}	1664 (1249)	65 (73)	0.3061 (0.3061)	0.9975 (0.9975)
T_{max}	2143 (1643)	84 (96)	0.3063 (0.3114)	0.9967 (0.9881)

Tab. 3 - Results of external drift investigation for temperatures spatial interpolation. In brackets values for the irrigation season. T_{dm}: mean daily temperature; T_{min}: minimum temperature; T_{max}: maximum temperature.
Tab. 3 - Indagine della serie storica considerata per la ricerca di forzante tra temperatura e quota. Tra parentesi vengono riportati i parametri relativi alla stagione irrigua. T_{dm}: temperatura media giornaliera; T_{min}: temperatura minima; T_{max}: temperatura massima.

The minimum mean hourly value recorded between 3 and 9 a.m. and the maximum mean hourly value between midday and 4 p.m. were used as minimum (T_{min}), and maximum temperature (T_{max}), respectively. A minimum of four hourly records in the considered time intervals was deemed necessary for defining T_{min} and T_{max}. The mean daily temperature (T_{dm}) was used only when more than 16 hourly records per day were available.
Extra-atmospheric radiation (Rg_0) and the latent heat of evaporation (L) are computed as described by Eccel *et al.* (2004). The Hargreaves' equation accounts for solar radiation reaching the ground by using the daily thermal range ($T_{max} - T_{min}$): the larger the range, the more shortwave solar energy reaches the ground and becomes available for evaporation. I_r values are manually introduced into equation (1) (Fig. 2). When field capacity (f_c) is reached for a given day, a fifth of the residual water surplus is made available on the following day under the

Calcolo del fabbisogno idrico IDEA-Gis

Stima del contenuto d'acqua nel terreno dal giorno 2010-04-06 al giorno 2010-04-11.
Previsione per oggi e fino al 2010-04-14.



	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	*12-Apr*	*13-Apr*	*14-Apr*
Evapotraspirazione [mm/giorno]	2.3	2.4	2.5	2.7	2.6	1.5	*2.7*	*2.6*	*2.7*
Precipitazione [mm/giorno]	--	--	--	--	--	0.6	--	--	--
Irrigazione [mm/giorno]	--	--	--	--	--	--	--	--	--
Contenuto d'acqua [mm/giorno]	120	117	115	112	109	108	106	103	100

Fig. 3 - irri4web in exploratory mode. Graph: soil water content W[t]. Lower part: water balance terms.
Fig. 3 - irri4web in modalità esplorativa. Viene riportato il grafico del contenuto idrico del suolo W[t] e, in tabella, i contributi idrici del bilancio.

model	Year days	Year perc.	Season days	Season perc.
Prec ~ quota	329	25.61	273	27.55
Prec ~ x+y	145	11.32	106	10.70
Prec ~ 1	807	63.00	612	61.76

Tab. 4 - Summary results for spatial correlation of P. Top to bottom: external drift (elevation), trend (x+y: geographic coordinates) and zero hypothesis of absence of links were tested.
Tab. 4 - Risultato riassuntivo dell'analisi della ricerca di correlazione spaziale. Dall'alto al basso: forzante (quota), trend (x+y: coordinate geografiche), ipotesi zero (assenza di legami con tali variabili nei dati di precipitazione).

		MAE [°C]	MSE [°C^2]
T_{dm}	LM	1.3439 (1.1944)	0.3955 (0.2844)
	MBLM	1.5050 (1.3569)	0.4424 (0.3137)
T_{min}	LM	2.2188 (2.1221)	1.1204 (0.9722)
	MBLM	2.4246 (2.3441)	1.2310 (1.0870)
T_{max}	LM	2.0227 (1.8928)	0.7644 (0.7047)
	MBLM	2.0884 (1.9468)	0.8183 (0.7521)

Tab. 5 - Comparison between interpolation errors in Linear Model (LM) and Median-Based Linear Model (MBLM) by Leave-One-Out Cross Validation (LOOCV) technique (75th percentile of Mean Absolute Error - MAE - and Mean Standard Error - MSE). In brackets values relevant to the irrigation season. T_{dm}: mean daily temperature; T_{min}: minimum temperature; T_{max}: maximum temperature.
Tab. 5 - Confronto tra errori di interpolazione tra modello lineare (LM) e modello lineare basato su mediana (MBLM) mediante cross-validazione "leave-one-out" (LOOCV). Sono riportati i valori del 75° percentile di errore assoluto medio (MAE) ed errore standard (MSE). Tra parentesi sono riportati i valori relativi alla stagione irrigua. T_{dm}: temperatura media giornaliera; T_{min}: temperatura minima; T_{max}: temperatura massima.

hypothesis that P_p is driven by f_c. As this application aims at the optimization of water use, the final user can monitor soil water content (Fig. 3).

Spatial interpolation

As irri4web is a web-oriented, server side application, it applies spatial interpolation of precipitation and temperatures on any map point, interactively defined by the user, by using meteorological data collected at the surrounding stations. This requires the use of an interface between the web server (Apache) and a statistical software (R), which feeds the predicted values into the water balance model. MySQL is used as a data store for meteorological records (DBMS) while PostgreSQL + PostGIS manages all georeferenced data (RDBMS). These database management systems are used as informative layers.

This working approach simplifies the Input/Output process for spatial interpolation thus boosting overall performance. In geostatistics, it is a well established procedure (Kitanidis, 1997) to conduct a correlation analysis between dependent variables (in this case, temperature and precipitation) and their possible driving factors, prior to parameter estimation. In this case, the established, day-by-day statistical relationship with altitude - vertical temperature gradient or, more generically, external drift (ED) - was used for temperature. This approach follows the "regression kriging" as proposed by Hengl *et al*. (2007). A finer analysis was necessary for the spatial interpolation of precipitation events.

Temperature

Preliminary tests were conducted on the data series collected by IASMA, in order to identify the best approaches to the DSS implementation. Meteorological data series cover 2546 days, from 26th Oct. 2001 to 10th Oct. 2008. A significant linear trend with elevation was found in 2156 cases (84%) for T_{dm}, with a R^2 ranging from 0.307 to 0.997. During the irrigation season (1st Mar. to 30th Oct.), the number of days with a significant trend increases to 97%. Extended results are summarized in Tab. 3.

In order to shorten the response time of the DSS, calculations rely on data from a small subset of the 17 available meteorological stations depending on the selected point. Due to the low number of measurement sites and to their uneven distribution, the assumptions for a valid linear regression model (LM) for ED were hardly met. For this reason, a median based robust regression model (MBLM) was preferable to LM (Theil, 1950; Lukasz, 2007). Nevertheless, the accuracy of these methods was compared. The significance of Theil slope coefficient was determined by Kendall test (Sen, 1968; McLeod, 2005). Leave-one-out cross-validation (LOOCV) (Cressie, 1993) was performed on daily temperatures residuals for a comparison of LM vs. MBLM, using ordinary kriging (OK). Independence of residuals obtained with LOOCV was tested with Wilcoxon test.

Precipitation

Precipitation was investigated for 2563 days, from 22nd Oct. 2001 to 29th Oct. 2008. In 1281 cases (50%) at least one precipitation event was recorded in at least one station. Up to 991 (57%) rainy days were counted out of a total of 1731 during irrigation season. No clear link or trend between rainfall

		MAE [mm]		MSE [mm^2]		ME [mm]	
P	kriging	5.948	(6.026)	6.241	(6.596)	6.273	(6.273)
	IDW	6.031	(6.201)	7.036	(7.415)	2.177	(2.177)

Tab. 6 - Leave-One-Out Cross Validation (LOOCV) error comparison for precipitation. 75th percentiles are reported. Values for irrigated season in brackets. MAE: Mean Absolute Error. MSE: Mean Standard Error. ME: Mean Error (bias). IDW: inverse-(squared) distance-weighted mean.
Tab. 6 - Confronto tra errori di interpolazione IDW e previsione mediante kriging stimati mediante cross-validazione "leave-one-out" (LOOCV). Tra parentesi sono riportati i valori relativi alla stagione irrigua. Sono riportati i valori del 75° percentile di errore medio assoluto (MAE), errore medio standard (MSE) ed errore medio o bias (ME). IDW: media pesata con l'inverso delle distanze al quadrato.

amount (P) and elevation was found (Tab. 4). Thus, a general model is unlikely to suit the data set.
This problem was addressed by selecting the best interpolator according to the empirical semivariogram and by performing a day-by-day LOOCV (Fig. 5a). Concomitantly, a LOOCV for inverse-squared-distance-interpolation method (IDW, Eccel *et al.*, 2004) was carried out. The independence of crossvalidated residuals was tested with Wilcoxon test and performance between the two methods were compared (Fig. 5b).

Results and Discussion
Temperature
The differences between interpolated values and measures of temperature (residuals) were calculated for both LM and MBLM. The 75th percentile of the Maximum Absolute Errors (MAE) and Mean Square Errors (MSE) are reported for model comparison, as these error distributions are strongly influenced by irregular, confined anomalies in data recordings (Fig. 4, Tab. 5). Daily comparisons (Wilcoxon test) of residuals show no significant difference between methods. For T_{dm}, Kendall test applied to MBLM slopes shows that ED occurs in 82% of cases (up to 96% during the irrigation season). Similarly, in the 57% (85%) and 84% (96%) of cases, ED occurs for T_{min} and T_{max}, respectively. Moreover, from 1st Mar. to 30th Oct., when the DSS is supposed to be used, the frequency of occurrence of ED is similar between methods (Tab. 3). LM is always more precise than MBLM, but the latter is preferred for the DSS implementation due to its robustness.

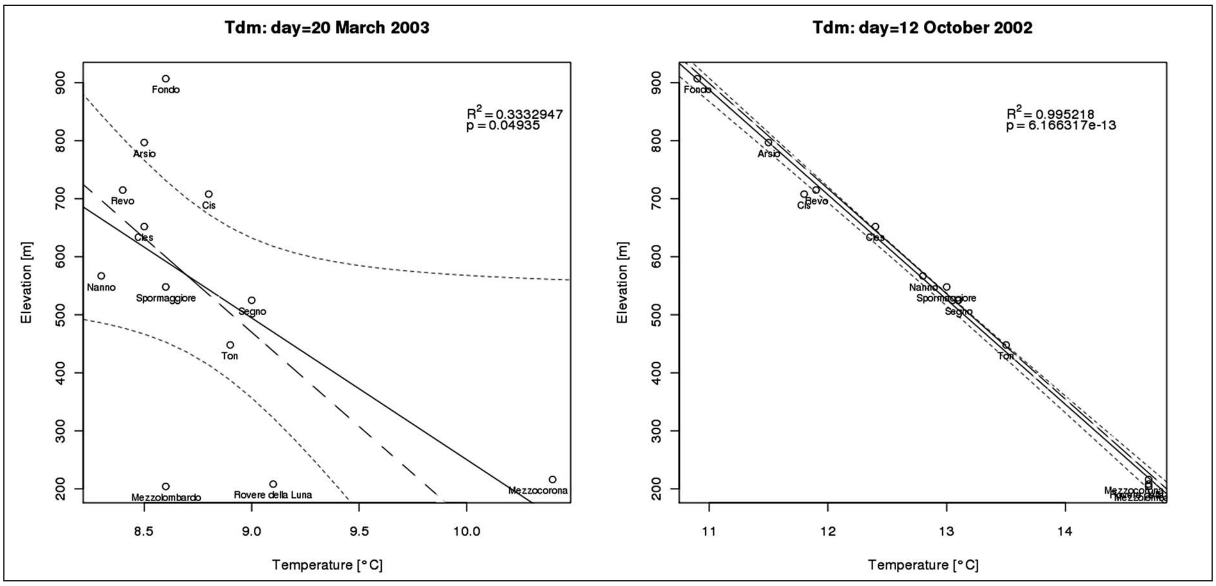


Fig. 4 - Fit comparison for temperature vertical lapse rate at the ground. Linear Model (LM, continuous line) and Median-Based Linear Model (MBLM, long dashed line): gradient is significant (right) and not (left). Short dashed lines represent confidence interval at 95% significance.
Fig. 4 - Temperature medie giornaliere in funzione della quota: confronto tra modello lineare (LM, linea continua) e modello lineare basato su mediana (MBLM, linea a tratteggio lungo), nel caso di assenza di legame lineare tra temperatura media giornaliera e quota (sx) e di presenza di un gradiente termico statisticamente significativo (dx). Le linee a tratteggio fitto rappresentano l'intervallo di confidenza al 95%.

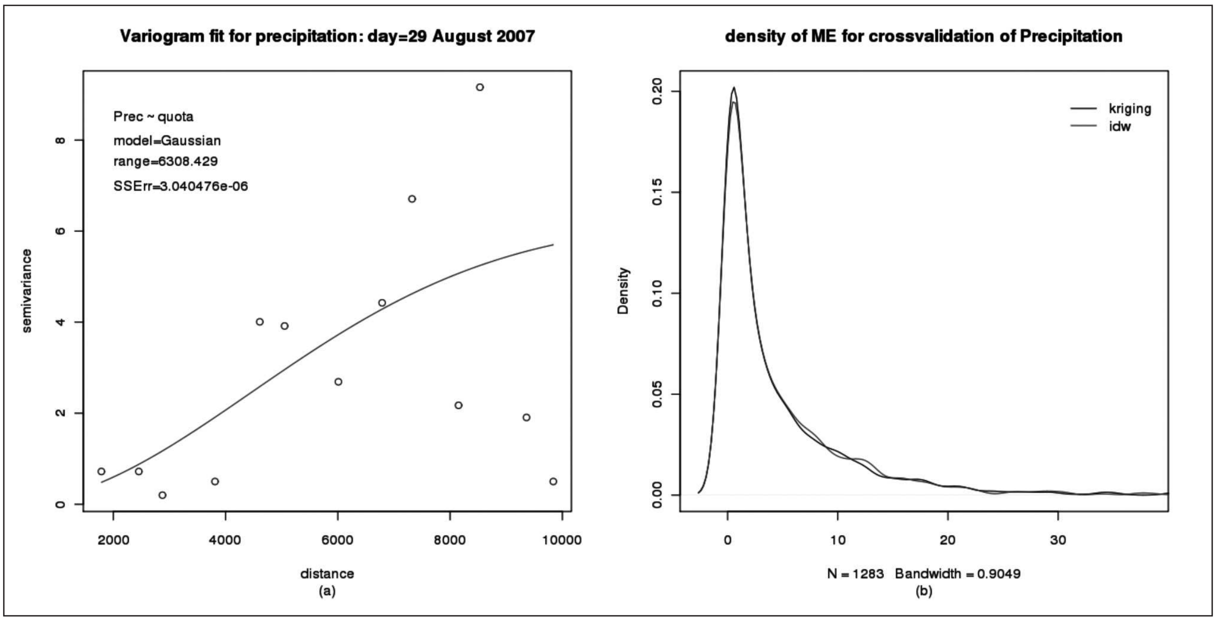


Fig. 5 - Empirical semivariogram interpolation example (a) and performance comparison between kriging and IDW (Inverse-(squared) Distance-Weighted mean).
Fig. 5 - Interpolazione del semivariogramma empirico (a) e confronto di performance tra kriging e IDW (media pesata con l'inverso della distanza al quadrato).

Precipitation
In the 98% of rainy days, the Wilcoxon test showed the independence of LOOCV daily residuals for both IDW and kriging. The comparison of the density distribution of the MEs showed a similar performance of the two methods. When the MAE was used as comparison parameter, in 67% of cases the predictions yielded by the IDW were better or equivalent to those observed by the kriging. Working with non-validated data series led to occasionally strange spatial configurations and both methods proved poorly descriptive. More details on these errors are given in table 6. Kriging performed considerably better than IDW only when data showed good spatial correlation. IDW was preferred in the DSS implementation, as it was more robust in all the cases where the parameterization of the precipitation event is hardly assessable.

Web interface
The end user of the DSS identifies a point of interest (POI) through the webGIS interface based on the p.mapper software library (Burger, 2008). Consequently, the relevant information is retrieved from RDBMS: the elevation attributed to the POI is that of the nearest DTM cell (stored as a vector point layer); land use is inferred from the "Effective Land Use Map" (CUSR) (PAT, 2006); the identification codes of meteorological stations falling into a 5-km-radius circle (if the number of stations is less than 4, the radius is doubled) come from the meteorological database; the depth and structure of soil are retrieved from the CPp and are used for f_c and wilting point (w_p) assessment.

The T_{min}, T_{dm}, T_{max}, and P are retrieved from the DBMS and spatially interpolated (Pebesma, 2006) for the 7 days preceding the present date for all the stations that meet the position requirement. k_{cd} is fixed according to the CUSR for the given period of the year. The available water content (awc) and the portion of water rapidly available for roots (raw) are calculated. The water inputs and outputs received by the soil are then quantified by spatial interpolation, for the seven days preceding the query (current date).
Evapotranspiration is calculated for the 3 days after the actual user request, by applying MBLM kriging to 7 forecast points. For this task we use temperature forecasts provided by Meteotrentino (the regional meteorological service) on 7 stations by Kalman filtering (Galanis *et al.*, 2002) of the meteorological model from Reading European Centre (ECMWF). Rainfall is interpolated by IDW using 4 ECMWF points surrounding the pilot area (Fig. 1). This offers the opportunity for further resource optimization to the whole DSS system. Graphs and tables are served to the user.

Conclusions

The envisaged changes in the patterns of precipitation and the need to preserve valuable crops require that good practices in agriculture are implemented, supported by the development of modern tools for modelling water requirements. Thus a Decision Support Service (DSS) has been developed to follow growers' syndicates in their irrigation management. This DSS focuses on reduction of wastes, by modulating necessary supplies during the growing season. System efficiency is based on the minimization of user inputs, on robust spatialization techniques and on the scalability offered by interoperable open source software (Ciolli *et al.*, 2006).

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