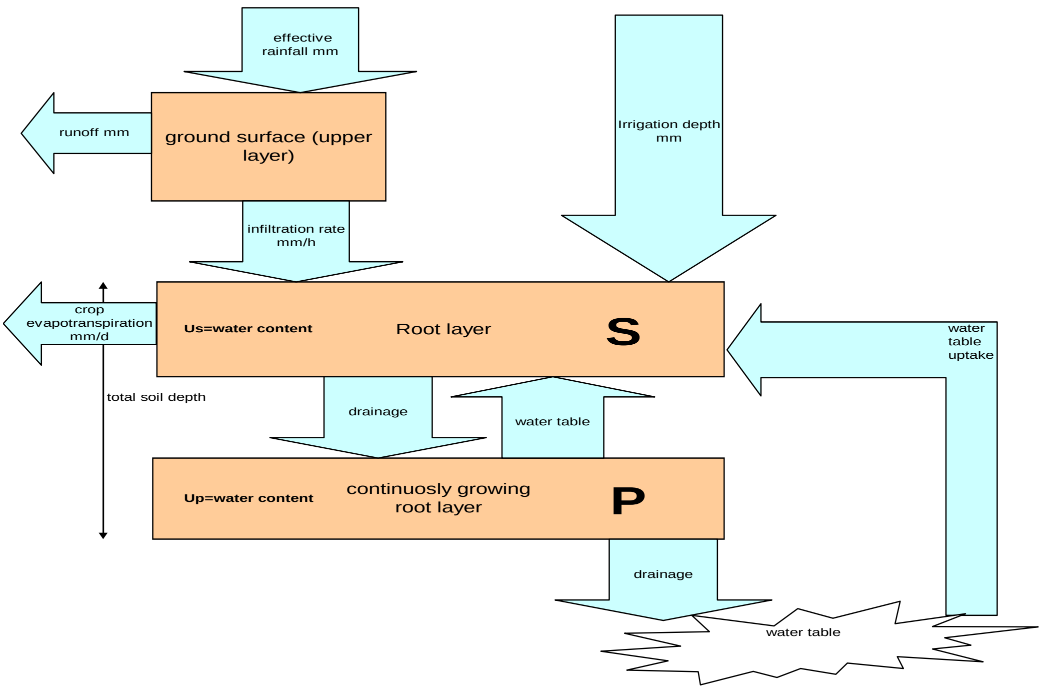
IRRIFRAME: IT Irrigation Advisory Services for Farm Water Management

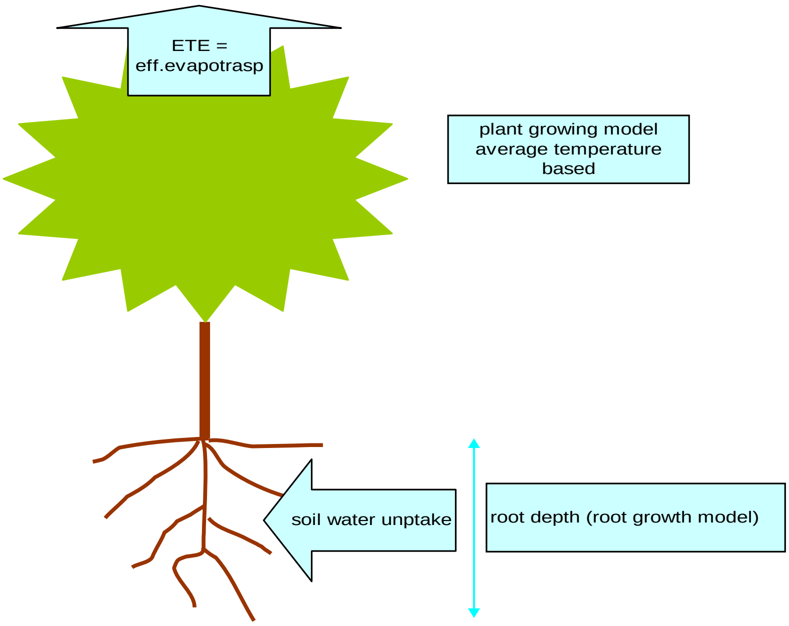
IRRIFRAME: IT Irrigation Advisory Services for Farm Water Management service is based on a water balance model aimed at crop irrigation management at a field scale and therefore the processes and calculation simulated by the model reflect such aim. The model has a structure that is concerned with the soil-plant-atmosphere continuum. It includes the soil, with its water balance; the plant, with its development, growth; and the atmosphere, with its thermal regime, rainfall and evaporative demand

The model has been simply summarized in the following diagrams:

Soil model



evapotranspirative model



The main processes simulated by the model are as follows:

1. ***Water dynamics in soil.***. It is the key process, the other processes simulated are affected by this calculation which is based on a tip in box model, hourly calculations and considering three different soil layers:

    - Soil surface layer: it take into account of the ground roughness created by tillage management
    - Root layer: this is the volume of soil explored by the roots. For fruit trees this is fixed, for other crops it varies over time, according to growth stages
    - Bottom layer: this is the layer below the “root layer” and will be explored in the next step by growing roots.

    For the soil surface layer the soil’s ability to store rainfall, is estimated based on its roughness, which is generated by the different kinds of tillage. For the other two layers, the water storage is estimated applying pedotransfers based on the soil particle size.

    Such pedotransfers have been empirically obtained using data provided by the Istituto Sperimentale per la Nutrizione delle Piante which has been the subject of extensive field trials.

    For each step in the calculation process, water exchange (which is estimated to be constant for each step) between the various layers is evaluated and updated at the end of each step, on a continuity equation basis.

    The model calculates run off fractions as difference between rainfall intensity, upper layer water storage and hourly soil infiltration rate. Run off is considered by the model as total loss.

    The amount of water which penetrates is given by the maximum infiltration rate which is calculated based on the sorptivity and the hydraulic conductivity of the single layer, affected by the specific soil particle size.

    Applying Driessen, the amount of water which moves between the layers of the soil profile is the water which exceeds single layer water storage; water drainage from the bottom layer is a total loss for the system.

    The soil water content of the two lower layers (root and bottom layer) is available to meet crop water requirements.

2. ***Crop growth*** this refers both to the sequence of development phases, and to root system growth. The model does not take into account the accumulation of biomass.

    2.1. **Crop development** – Crop growth is simulated, according to the specific crop chronology, starting from the seeding, transplanting, or vegetative recovery for fruit crops. The change in crop stage is calculated by means of degree day, which are specific for each crop growth stage. There is a minimum threshold of such daily data, specific for each crop, as under this limit the crop does not grow. This data has been supplied by ARPA SMR, while the minimum threshold is derived from bibliographical research which has been adjusted using local historical data.

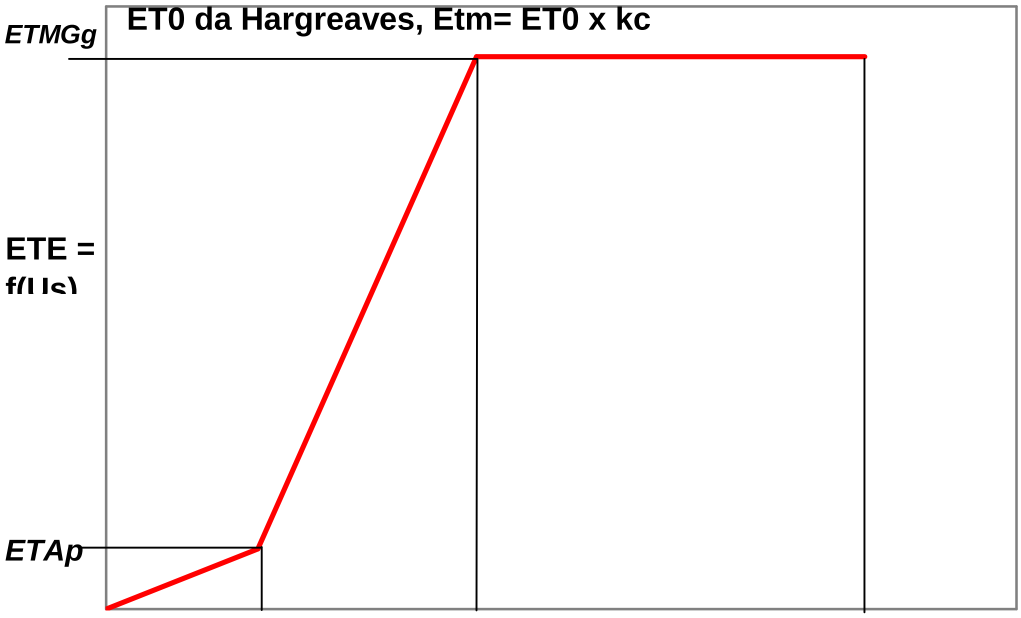
    2.2. **Root system growth** – According to the method proposed by F.Danuso for Bidrico models, root system growth is calculated based on a function which estimates the effect of

(i) daily temperature; (ii) soil water content of the layer beneath the roots; and (iii) the growth stage, on the theoretical maximum growth rate of each crop (provided by experimental research conducted by the CER on crops and soil in Emilia Romagna). For fruit tree crops a fixed layer which is constant over time has been used.

3. ***Crop water requirements*** – These are calculated applying the evaporation theory, following these steps:

   3.1. **Crop evapotranspiration under standard conditions** - We obtain the evapotranspiration data under standard conditions, starting from crop evapotranspiration reference data (ETo) provided daily by ARPA SMR (using Hargreaves equation) which refer to a 6.25 km^2 geographical grid covering the whole regional plain area. Then we apply the FAO k_c factor, specific for each crop and each growth stage and, in many cases, correct it with local research carried out by CER. The k_c factor is changed day by day, between stages, according to the continuity equation.

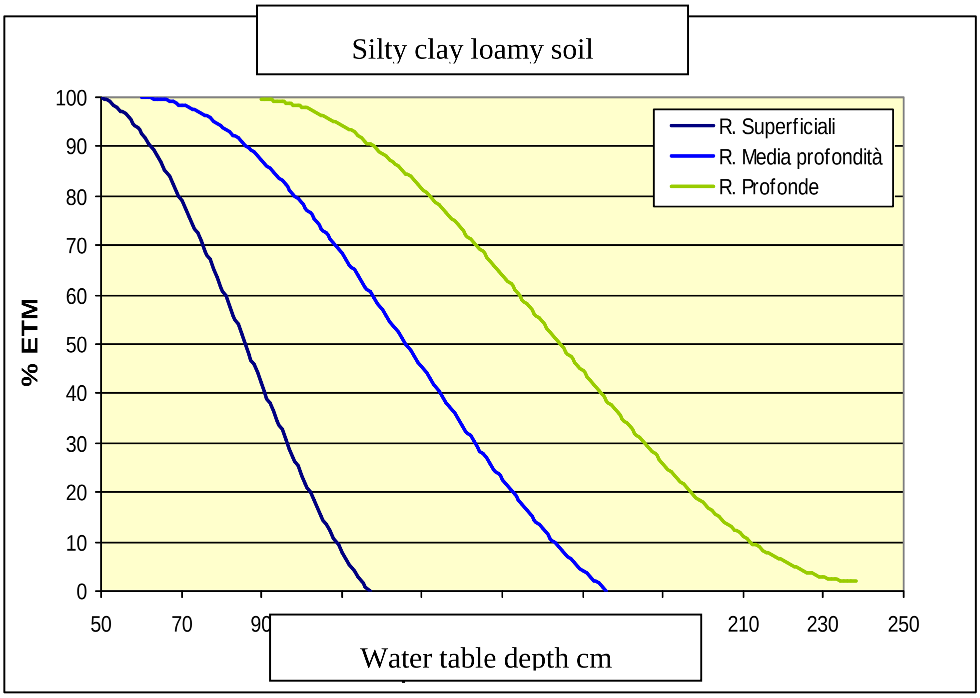
   3.2. **Crop evapotranspiration under non standard conditions** – In this case non standard conditions means poor soil water content that causes water stress in crops. According to the FAO paper n.24 theory that set up a specific soil humidity level under which crops reduce their evapotranspiration rate, we calculate the real crop evapotranspiration under field conditions



4. ***Water table contribution*** – The model does not evaluates the capillary rise from shallow water table but the water table contribution to crop water requirements expressed in terms of percentage of crop evapotranspiration. This is calculated using water table depth, soil particle size, crop soil water exploitation capacity and root system depth. Nine years research was carried out to find out the water supply reduction by applying constant water table depth to

several crops. We developed nine empirical equations which describe the relationship between (i) the percentage of crop evapotranspiration due to capillary rise from the water table, (ii) water table depth, (iii) three soil textural classes interacting with three crop clusters based on their root system depth and crop soil water exploitation capacity.

Below the graphics shows three equations of nine:



5. Determination of the irrigation depth

Once soil/plant water balance has been calculated, the model sets the water to be applied to the crop, i.e. the difference between the range values of the two soil water available thresholds. The values were calculated as a result of several years of field research, and are specific for each crop, growth stage and irrigation system (drip, flood, sprinkler). They are suited for better crop growth and to have maximum yield, changing day by day according to the continuity equation.

The model compares measured soil water content with the lower threshold daily; when the minimum value is reached, we calculate water irrigation depth as the difference between the thresholds.

The upper threshold may be equal to field capacity, or, usually lower to it, to avoid both soil water depletion not turned into yield, and to have a lot of dry soil to store rainfall.

The calculation of the irrigation depth plays a key role in the model, affecting the other steps so much that it characterizes the model as exclusively aimed at field scale irrigation.

6. IT Architecture of IrriFrame

Irriframe has been developed by AltaVia on .NET 4, ASP.NET MVC and Microsoft SQLServer2012 and is hosted on cloud servers.

The platform fully implements the REST methods through the ASP.NET MVC framework.

The Model-View-Controller (MVC, Figure 3.) architectural pattern separates an application into three main components: the model, the view, and the controller.

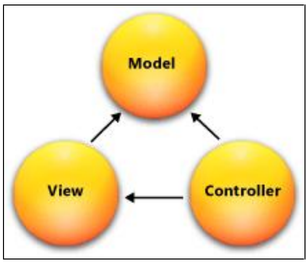


Fig. 3: MVC architectural pattern

The MVC framework allows the Test-driven development (TDD) methodology, a software development process that relies on the repetition of a very short development cycle: first the developer writes an (initially failing) automated test case that defines a desired improvement or new function, then produces the minimum amount of code to pass that test, and finally refactors the new code to acceptable standards.

REST stands for Representational State Transfer and it is a method for retrieving content from an HTTP endpoint. REST's most notable feature is that it is stateless. In other words, each call has all the necessary information for the server to process the request. REST allows to develop applications which are easy to maintain, flexible and amenable to change.

The architecture of Irriframe is outlined in Figure 4.

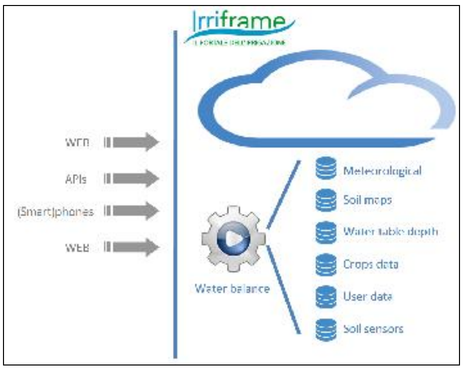


Fig. 4: Irriframe platform architecture.

The Irriframe services can be accessed by the different kinds of users in many ways. Final water users browse the information via Web and a smart phone APP. For the water managers Irriframe can be integrated with the Water Boards GIS applications by means of the REST direct calls.

6.1.Relational database

The application uses a relational database that includes more than 70 tables. The database is organised in informational areas according to the following scheme:

1. Knowledge base area
    a. model configuration parameters
    b. model and crop parameters (Kc, crop stages..)
    c. lookup lists (managed crops, irrigation systems..)
2. Area information
    a. Meteorological data
    b. Water table depth data
    c. Soil information
3. User information (registered users only)
    a. User and farm description
    b. Detailed crop description
    c. User data
        i. Rainfall
        ii. Irrigation gifts
        iii. Water table depth data
        iv. Start and stop crop date
4. GIS data
   The GIS maps are managed in ArcInfo format (shapefiles) and are stored in a directory outside the database. The polygon identifiers of the maps are dynamically linked to the information stored in the database (meteorological and water table stations, soil units..) . This allows information retrieval according to the user clicks on the GIS maps.

6.2.External data importation module

This module is an agent in charge of data upload which runs every hour. It uses both ASCII files and external web services and imports data into the database performing data consistency checks. The module is able to read data from several sources and several information providers.

6.3.IrriSMS

IrriSMS is a server service which uses the same business layer and database as the web application and is in charge of:

- Building up the list of SMSs to be sent for a certain day
- Running the water balance and formatting the irrigation information for SMS
- Queuing the SMSs
- Calling the SMS gate provider
- Managing the required resend in case of wrong dispatching
- Logging the SMSs sent

- Alarm messaging for the server operators

6.4. Irriframe Mobile

The Web pages have a light graphical structure and can be well displayed on a mobile browser. The same information are automatically sent via SMS to many more farmers: most of them are registered into the system by technicians and do not need Internet connection to get the irrigation scheduling.

The main functionalities of the platform can also be accessed by an APP for Android and IOS called “Irriframe Voice” (Figure 8.).

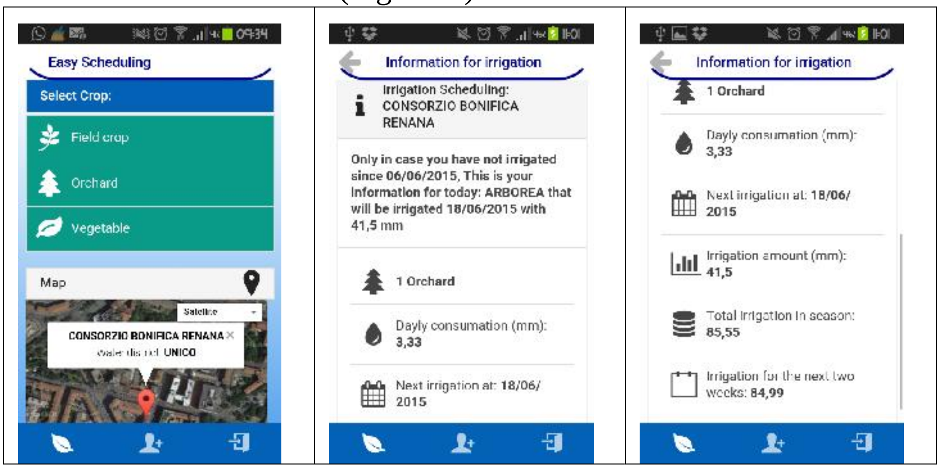


Fig. 8: Screenshots of Irriframe Voice APP for Android & IOS

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