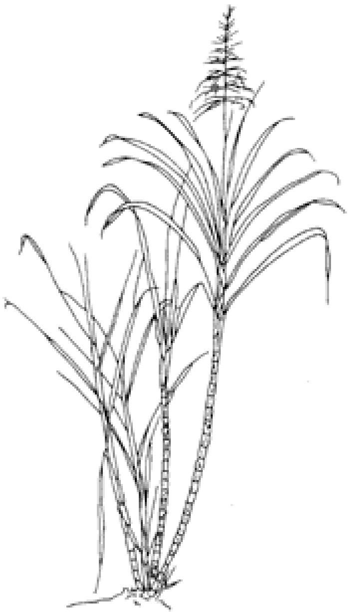
KANEAU

Irrigation Management in Sugarcane Estates (KANEAU)



Instruction Manual

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1. Sugarcane irrigation

1.1. Introduction

Irrigation is a major factor in sugarcane growing. Indeed, sugarcane is one of the most water-demanding crops after rice. For example, depending on the zone, it may take more than 1000 millimetres, i.e. 10,000 cubic metres of water, for a yield of 100 tons per hectare.

However, with climate change and population growth, farm managers are not only faced with a permanent concern for environmental protection but also with shortages in available water and increasing production costs; in this restrictive context, reducing agricultural water consumption becomes an ongoing challenge. In the most frequent case of estates, the main problem is linked to the energy required to pump and distribute water. Irrigation costs roughly amount to a third of total cropping costs. That is why irrigation is an expensive but essential technique. It is thus necessary to correctly manage this input by supplying sugarcane fields with the amount of water strictly needed by the plant, but also through optimum management of the equipment and, in particular, by reducing network water losses. Use of an automated system to manage irrigation thus becomes of paramount interest.

In this work, particular thought was given to developing water management rules on a field scale, and not to the choice of a water balance model, which can be considered solved. The water balance model we used here is a simple model with two reservoirs, written under Visual BASIC (fig. 1). The entire software is necessarily built around a relational database.

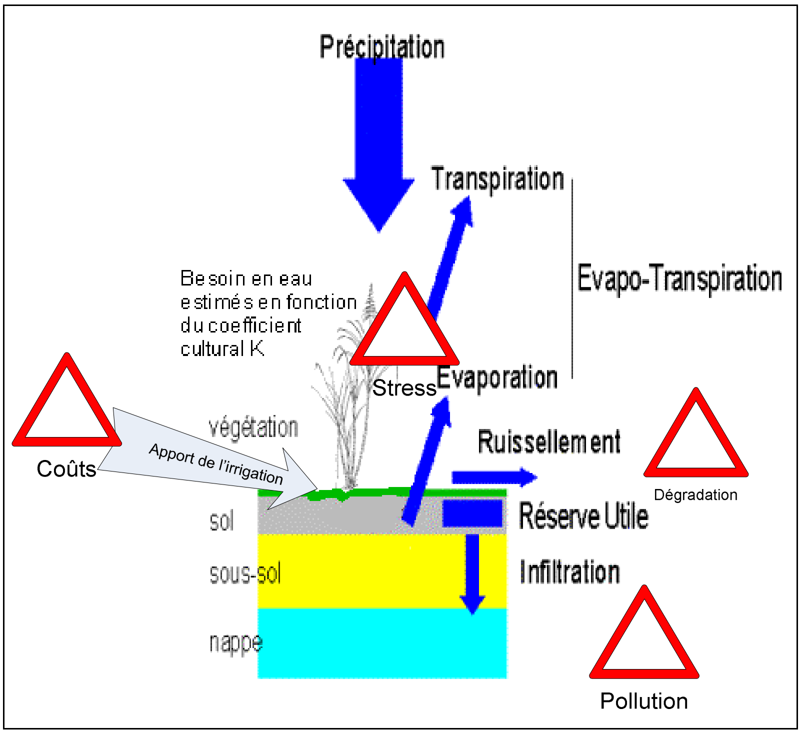


Figure 1: The water cycle in the environment

Based on our experience in African sugarcane fields, we set out to create an easy-to-use software capable of dealing with managers' problems on such farms.

In estate farming, irrigation gives rise to various difficulties; in our work we adopted the variability and unpredictability of events as the essential difficulties. The first involves field equipment (e.g. variability in irrigation equipment) and the second operational concerns (e.g. variability in energy supply). Given the lie of the land, there may be different lateral lengths and different discharge conditions within the same field. This results in non-respect of the irrigation cycle, which is one of the most complex consequences to take into account. In fact, non-respect of the irrigation cycle can have several causes: energy supply, equipment breakage, cropping techniques, equipment maintenance.

In such a context, how can sufficiently sound irrigation advice be given that is likely to be applicable by users?

To succeed, it is necessary to put forward some simplification hypotheses that take into account the results of the daily water balance model, along with all the constraints, and will make the advice not only calculable but also reasonably applicable.

1.2. Definition of the irrigation season

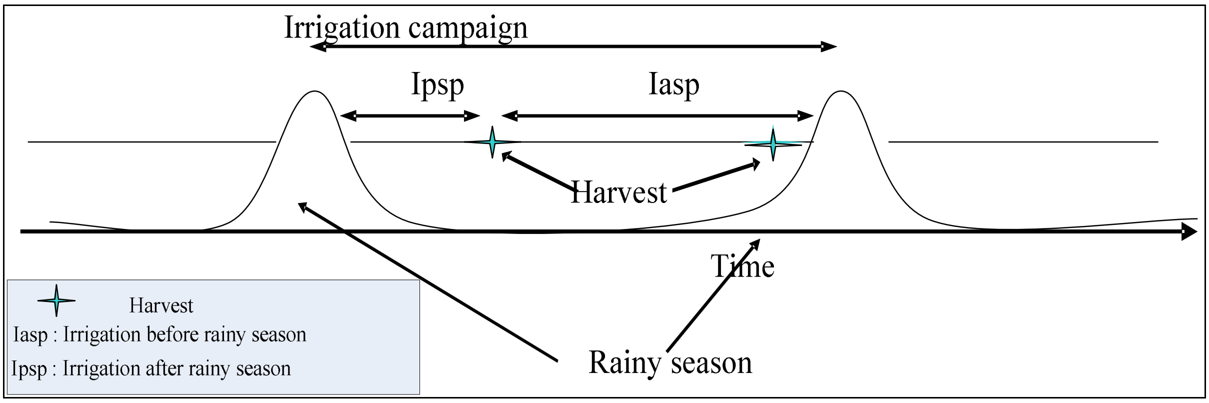


Figure 2: Irrigation season diagram

This definition applies to a one-year growing period, the most frequent in the northern hemisphere. However, the Kaneau software can take into account longer crop growing cycles. An irrigation season begins on the date irrigation has to be resumed after the rainy season and continues up to the date irrigation is halted before the next rainy season.

2. Basis of the model

2.1. General

1] - The field is considered as a whole. The amount of water is calculated for the whole field whatever its heterogeneity.

2] – For the solid set system, as pressure variations cannot be taken into account in detail, the amount of water is necessarily calculated on the basis of only one sprinkler generalised to the whole field. This rationale is derived from the basic principle that calculated application time will always be the same, whereas pressure at the sprinkler outlets will vary.

3] – The irrigation schedule has been abandoned in favour of a cycle duration systematically readjusted at the end of each irrigation schedule. The cycle is therefore the basic concept taken into account in this project.

If there is no interruption in irrigation, the cycle must match the theoretical irrigation schedule, for which the duration of a cycle may roughly last from 5 to 10 days depending on equipment design.

The beginning of the cycle, corresponding to the start of an irrigation schedule, is determined by the user. Irrigation then proceeds, possibly with interruptions for movement of the equipment, equipment breakdowns, or even rainfall. Irrigation is stopped when the amount of water initially computed has been delivered.

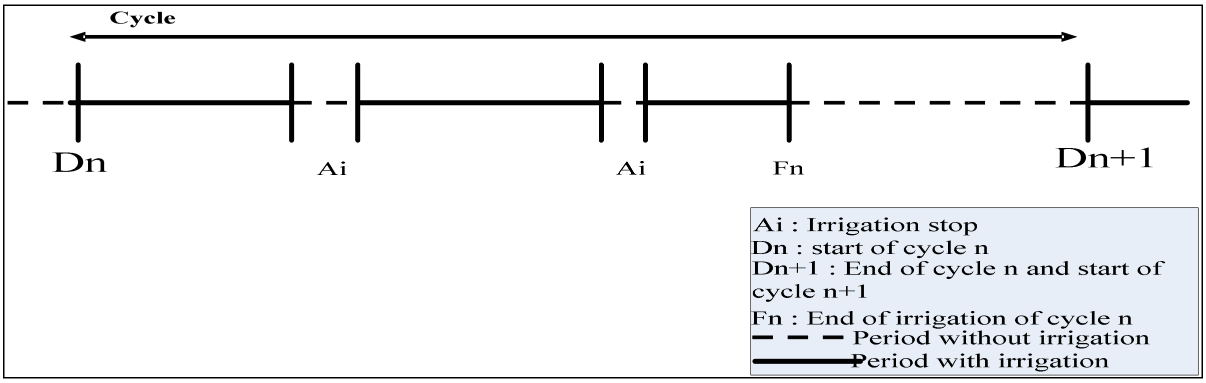


Figure 3: Diagram of irrigation cycle

The dates Dn and Dn+1 define the duration of the irrigation schedule. In that way, certain unpredictable irrigation interruptions can be integrated, in both time and duration, without considering them in detail. The irrigation cycle is then regarded as a set of events that cannot be rendered discrete.

Realistic sampling of the pressures at sprinkler outlets in the field would enable more effective monitoring of pressure variations mainly linked to variations in the energy supply. In this case, to within the approximations associated with sampling, this parameter will be integrated in its entirety by allotting an average pressure value to the field.

In brief, as far as medium pressure sprinkler irrigation is concerned, the only fixed parameters adopted are:

* The starting date of the schedule (certain)
* The computed irrigation duration (estimated from the water balance model)

All others parameters are essentially variable and unpredictable.

The variables required for water management are calculated from the planned net amount of water (DNP), which is the entry variable directly resulting from the water balance model. In fact, any irrigation management process will be based on this model with specific adaptations depending on the irrigation systems.
Once the water balance model has computed the amount of water, the objective will be to check the quality of its application after the event. This assessment is carried out using value criteria such as:

* The effective rank of the current cycle compared to the theoretical cycle.
* An operational implementation index (IREO%) which expresses the quality of water application. This should not be confused with the stress ratio (ETc.adj/ETc) which applies to optimum theoretical data, whereas this index applies to practical implementation conditions:

$$IREO\% = \frac{\overline{\overline{DqE}}}{\overline{\overline{DqT}}} * 100$$

Where: $\overline{DqT} = \frac{DBP}{TEj}$ mm (average amount/day)

$\overline{DqE} = \frac{DA * 24}{(D_{n+1} - D_n)}$ mm (actual average amount/day)

DBP = gross scheduled amount. It is the result of the water balance computation
DA = water actually applied

At the end of each irrigation cycle and at the end of the irrigation season, all cumulative data will be displayed, in addition to the conventional water balance data:

Recommended gross amounts
Water actually applied
Actual number of cycles carried out
Theoretical number of cycles
Water requirement shortfall (mm)
Operational implementation index (IREO%)

2.2. The database

The software interacts with an Access database.
A snapshot of the estate and the relations between the different elements making up the estate can be established in the database. For instance, information can be monitored to solve problems or draw up summaries easily. In other words, this constitutes a memory of the events occurring in the fields we are monitoring.

This database consists of 19 tables which store information concerning the fields, the equipment, the meteorology and all outcomes of water balance modelling and advice.
The meteorological parameters required to calculate evapotranspiration come from automatic recording stations. Rainfall and all the other data are entered manually.

All the hydraulic characteristics specific to the irrigation system and the field are inputted in two tables:

Computed data

Input data:
- the net amount of water, from the water balance simulation
- mean flow from the relation Q=f (P)
- network efficiency

Output data:
- irrigation time for a sprinkler
- the **actual** irrigation time for a complete cycle
- the amount of water actually applied, which will become a new input data item for computing the water balance of the following cycle.

Measured data
- The sprinkler pressures
- The irrigation resumption date.

2.3. Application to irrigation systems

2.3.1. The semi-permanent system

In this system, the laterals are set up permanently in the field; only the sprinklers mounted on the risers are moved. In most cases the laterals are in HDPE and fitted with automatic valves to fit the risers

Definition of the irrigation cycle.

According to conventional rules adopted (fig. 3), the cycle finishes when irrigation is resumed on the first sprinkler position on the lateral on date $D_{(n+1)}$. In this case, the duration of the irrigation cycle estimated by the difference ($D_{(n+1)}$–Dn) = Δ**D**, incorporates the various interruptions in irrigation, **without differentiating between them,** at the same time as normal lateral movements, along with the actual irrigation time.

These dates stored in the database can subsequently be used to estimate the non-irrigated time of the cycle, ΔD – DTC, where DTC is the true total duration of actual irrigation. However, by proceeding in this way, it will not be possible to differentiate between interruption times, apart from those due strictly to the displacement of equipment, unless the times and causes are carefully recorded.

As regards checking the amounts of water applied,, if the volumes used are estimated from the function Q= f(P), there will be no problems other than those related to measurement sampling as already mentioned. However, if they are measured with flow meters, the system needs to be clarified. Indeed, the volumes will thus be recorded each time the first sprinkler is in position ONE (1st position on the first lateral). This reading is useful for defining the end of a cycle and measuring the volume of water that has just been used; it also defines the beginning of the following cycle.

Thus, when reading the flow meter there are other sprinklers in operation; with the valve system, irrigation is not stopped when moving sprinklers so two successive cycles may be temporarily operating in the field at the same time. Irrigation interruptions or unforeseen variations in pressure would therefore affect those two cycles simultaneously. When estate irrigation is involved, such errors are regarded as negligible. In fact, over a longer period of several weeks, the compensation of the amounts of water applied between the two cycles can be considered sufficient.

Some simplification hypotheses specific to this system need to be put forward. The new difficulty in the simplification approach lies in sprinkler displacements:

1) The sprinkler displacement time on the lateral is overlooked
2) The actual irrigation time is regarded as being the same for each lateral
3) The first lateral may be considered as a guidance lateral for all the other laterals in the field.

This last item leads to the displacement of laterals not being taken into account, since irrigation monitoring is computed for the first lateral and applied to the whole field, on the assumption that all the events occurring on that lateral (interruptions, variations in pressure, rainfall, etc.) exist on all the laterals in the field.

The total cycle length is calculated: $DTC = TA*NC/NA$

Where: TA = Irrigation time
NC = Number of valves on the lateral.
NA = Number of sprinklers on the lateral.

This *guidance lateral* system appears sufficiently reliable to be correctly used for irrigation management in an estate.

2.3.2. The solid set system

In this system, all the irrigation equipment, pipes and sprinklers, remains permanently in the field. Irrigation is organised by sector; hydraulic valves at the end of each lateral are used to close or open water distribution.
The equipment in each field is correctly described and entered in the database. Thus the advice computed from the water balance model is displayed as irrigation time (H, Mn) and the amount of water to be applied is displayed in millimetres.
For the same kind of equipment, with the same spacing between laterals and the same sprinkler settings on the lateral, irrigation time and the amount of water applied are independent of the number of sprinklers.
If the computed water application time is considered to be identical in all the sectors of the field, an error or a degree of heterogeneity in water application can only come from pressure variations.
Management of the equipment in this system is much easier than in the previous one. Once all the characteristics of the equipment are properly described in the database, only the times and flow meter readings need to be inputted.

2.3.3. The centre pivot system

Because of its rotational movement, the centre pivot presents specific characteristics and maintenance constraints. For agronomists, the most notable characteristic is the variability in water application rate, which increases in line with the distance from the centre of the machine. At the end of the lateral, it can reach very high values (> 100 mm/h) which, depending on soil infiltration capacity, may involve degradations such as:

- subsoil leaching,
- run-off,
- erosion,
- compaction.

Management of the centre pivot irrigation method by the software results from a compromise between the hydraulic capacity of the soil, crop water requirements, the hydraulic characteristics of the equipment, and the water volumes actually available at the pumping station.

Another concern must be considered, though it is hard to take it into account; it is the daily water application rate, which is often insufficient during a boom period. That shortage explains the difficulty in achieving high yields with this type of equipment in the event of poor climatic conditions.
This type of irrigation management calls for sound knowledge of the soil's hydraulic characteristics.

2.3.3.1. Basis of modelling

Water volumes adapted to the crop's requirements depend on the volumes of water actually available and the network design; they also largely depend on the resolution of organizational problems. Two main organizational issues must be solved: is the centre pivot able to meet all the crop's water requirements? And if so, what is the water delivery limit to be adopted to reduce the risks of run-off ?

The nominal daily applicable amount (DNQA) is fixed and specific to one pivot. It depends solely on the hydraulic characteristics of flow and pressure designed by the manufacturer, under predefined operating conditions. Based on the daily crop water demand (BesQP), two situations can arise:

① BesQP < DNQA

The equipment is able to satisfy all the crop's water requirements.

② BesQP $\geq$ DNQA

The equipment only partially satisfies the crop's water requirements.

Where,
BesQP = ETo*Kc/eff (mm/d)
DNQA = DNA * 24/θ (mm/d)
DNA = nominal amount of water for the centre pivot (mm)

θ = corresponding nominal rotation time, in hours per revolution.
eff = irrigation efficiency

But in this case, the main aim is to limit the risks of erosion, at least at the far end of the lateral. To do that, it is necessary for the water delivery at the end of the lateral to be lower than the hydraulic conductivity, K, of the soil (mm/h), measured in the unsaturated phase. This information can only be obtained at the periphery of the field.

V is the time controller value which regulates the revolution speed. It is inversely proportional to the rotation time of the lateral and to the amount of water applied; it can be calculated by one of the following algorithms, established from the manufacturer's data and measurements in the field:

(3) $\mathbf{V_1 = a*10^{-n} * \theta^2 + b*\theta + c}$,

(4) $\mathbf{V_0 = a*10^{-n} * DBP^2 + b*DBP + c}$

The b coefficients are negatives in these two equations.

To satisfy condition (2) for no run-off, the V adjustment of the time controller will have to satisfy the condition $\mathbf{V \geq V1 = f(\theta)}$
Thus, the setting of the time controller corresponds to a faster speed

1st instance- BesQP < DNQA

As the daily nominal amount of water of the equipment is greater than the crop's daily water requirement, irrigation can be carried out under conditions close to maximum evapotranspiration (ETc). A time controller speed setting, V, will then be sought that most effectively reduces run-off, whilst satisfying the crop's water requirements as well as possible. Beforehand, the following relations must have been established, either from field measurements, or according to the manufacturer's data:

$$V_1 = f(\theta) \qquad (3)$$
$$V_0 = f(\text{amount of water}) \qquad (4)$$

Moreover, the crop's water requirements are fulfilled if the condition Vo = f (DBP) is respected.

If $\mathbf{V_0 \geq V_1}$, the software will advise $\mathbf{V_0}$, if not, $\mathbf{V_1}$ will be applied. In this event, the amount of water applied is less than the computed value (amount of water < DBP), and the crop's water requirements are not met, at least for this cycle. The decision whether or not to apply this advice is left to the user who will have to take into account environmental characteristics. If the environment is not very erosive, it will be possible to meet water requirements by applying **Vo**.

2nd instance - BesQP ≥ DNQA

In this case, irrigation must be daily, without interruption, and the crop's water requirements will only be satisfied if BesQP = DNQA. From a hydraulic point of view, this condition is not easy to achieve and can pose organisational and maintenance problems for farm managers.

Only one strategy is recommended by the software, the choice of the maximum revolution speed.

In fact, the maximum speed will always be obtained with V = 100% (the lateral makes one revolution in one day).

However, the farm manager could opt for another strategy, such as a slower speed. That choice will be made according to the soil infiltration capacity assessed by the hydraulic conductivity (K mm/h) measured in the unsaturated phase. This value, which corresponds to the graduations of the controller dial, may be entered via the “choix de la vitesse” data screen window.

If BesQP >DNQA, the crop's water requirements will never be satisfied. In that situation, the operator will merely have to "do for the best" and the software will enable him to record irrigation efficiency after the event.

2.3.3.2. Irrigation efficiency monitoring proposed by the software

Using a data-processing tool makes it possible to store parameters that are useful for subsequent calculation of irrigation efficiency ratios. These efficiency ratios are assessed at the end of the cycles. The amount of water applied, which will be taken into account in the following water balance, is computed according to two options:

- based on flow meter readings (default data),
- based on the relation DA = f (V), assuming that flow and pressure have standard values.

Knowledge of the consumption time (TC) and the amount of water applied DA, appears relevant:

$$TC\ (h) = (DA * 24)/(ETc.adj_j)$$

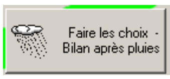
Moreover, this consumption time will make it possible to calculate the irrigation resumption date.

This consumption time is compared to the application time, TA = f (V) computed from the manufacturer's data. If the application time is greater than the consumption time, the crop's water requirements are not satisfied and we find ourselves in the situation where BesQP > DNQA.

The irrigation time is calculated by the relation: TA = f (V). If irrigation is interrupted, the actual irrigation application time then becomes: TEA = Σstops + TA
Where Σstops = the sum of the irrigation interruption times.
If TEA $\leq$ TC, irrigation interruptions do not affect the quality of the irrigation.
If TEA > TC, irrigation efficiency is reduced, and the quality of this irrigation will be expressed by the operational implementation index (IREO).

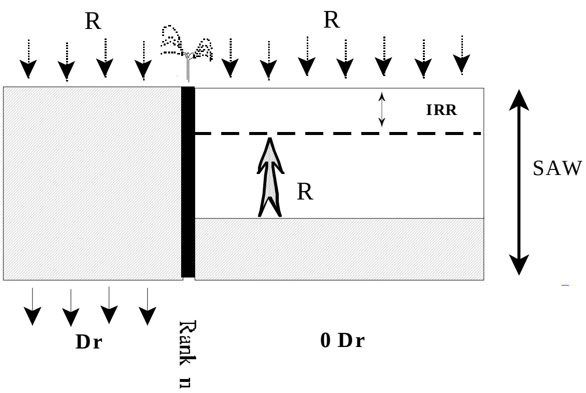
3. Procedure in the event of rainfall

When it rains during an irrigation cycle, the manager will have to decide whether to stop irrigating or continue and under what conditions. In estate farming, the rational principle is adopted that fields cannot be treated separately, without setting up heavy organisation that is not necessarily effective. The risk is then localized erosion that is limited in time, but an attempt must be made to reduce it as much as possible, by keeping as well as possible to the water balance and by implementing suitable cultivation techniques.

The incidence of rain occurring at instant t on sprinkler rank n is shown in figure 4. In order to leave the user free to decide, water balance computation after rainfall is *optional* and activated by an icon 

. This icon launches the calculation of the amount of water to be applied on the area remaining to be irrigated after rainfall. The flow chart in figure 5 shows the stages of this calculation.

Fig.4 - Effect of rain on an irrigated field



When the manager decides to interrupt irrigation during rainfall, the sequence of operations is as follows:

- Finish irrigating the current sector (if a centre pivot is involved, finish the rotation in progress).
- Note the rank of the n position.
- If there is a flow meter (operational), note the index.
- At this stage, entering the date will be pointless, since the irrigation schedule is not over.
- An irrigation interruption due to rainfall should be entered in the “BILAN des ARRÊTS d’IRRIGATION” template (i.e. irrigation interruption summary).
- Calculation of the water balance is launched after it stops raining.

The field irrigation cycle will thus end with another amount, DA2, and another application time, TA2. Consequently, the risks of erosion and water loss through drainage only exist on the area irrigated before position n (fig. 4). The extent of those risks obviously depends on the area already irrigated, therefore of the n rank of the current position. The problem does not arise in the same terms for centre pivots which, finishing their revolution, irrigate the totality of the field, whereas sprinklers do not finish their cycle.

At the beginning of the following cycle, the question will be to know what amount of water to adopt for computation of the water balance since the field received **TWO** different amounts. It is easy to understand that the results of the water balance computation will depend on the option chosen, and on the size of the area already irrigated when the rain started (hence of rank n). As the objective is a mean value for the field, an average amount will be calculated in line with the irrigated areas:

$$DA = \frac{n}{NP} * DA1 + \frac{(NP - n)}{NP} * DA2$$

- ***DA1*** = water applied before the rain
- ***DA2*** = water applied after the rain
- ***NP*** = number of positions
- ***n*** = rank of the current position

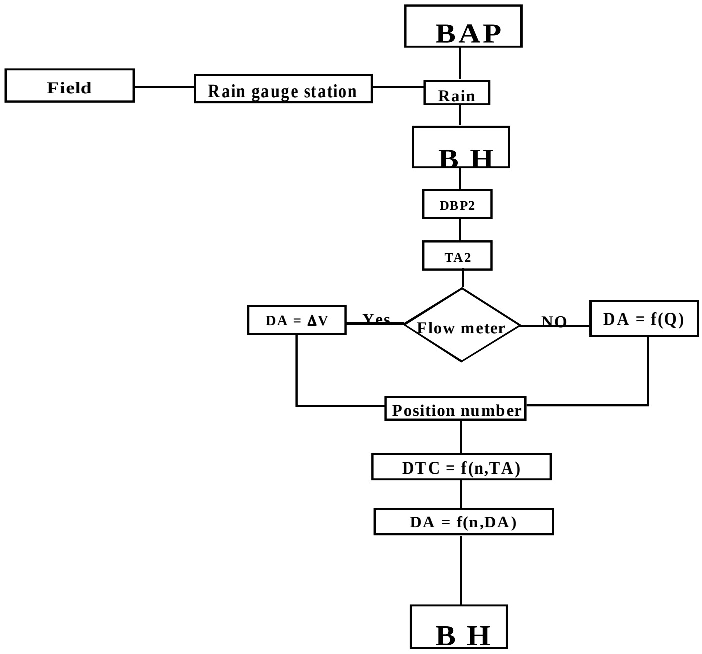
With the centre pivot, the water balance computation will be easier as it is done for a new rotation. However, the risk of erosion is greater because the centre pivot will finish its complete rotation in the rain.

The total irrigation time of the cycle then becomes:

DTC = n * TA1 + (Np-n) * TA2

TA1 = Irrigation time applied before the rain.
TA2 = Irrigation time applied after the rain.

Fig.5 - Post-rainfall water balance flow chart



4. Decision-making support in the event of water shortage

When the available flows at the pumping stations are insufficient to cover the totality of the theoretical water needs of all the fields, the software proposes an irrigation strategy to the manager in accordance with some relevant agronomic parameters. In fact, in these situations, the recurring question that arises, which is always tricky to solve, is to know how to use the limited available water; whether all available water is equally applied to all the fields or only to some fields with specific needs. The approach taken in the software is to rank fields according to a selection system. The software computes a set of solutions resulting from a compromise between the crop's water requirements, the historical field water balance, and the actual water availabilities in the network.
The objective is to irrigate only those fields for which the available upstream flow is sufficient to completely satisfy their water requirement.
To do that, the software establishes a classification of the fields to be irrigated according to two levels of priorities:

- The first level is agronomic and addresses the crop cycle. Plant canes (virgins) are ranked in priority 1 and ratoons under one month old in priority 2. Fields at the boom stage are ranked in priority 3.

- The second level of classification is bioclimatic. The criterion adopted is the ***relative stress index*** cumulated since harvest**:**

$$dcum = \left[\sum_{1}^{j}\left(ETc - ETc.adj\right)j \div \sum_{1}^{j} ETcj\right] * 100$$

Fields with the highest *dcum* must be irrigated as a priority. They are ranked in decreasing order of *dcum* values. The number of irrigable fields is then checked by further comparing the pumping station flows, Qs, to the iterative sum of instantaneous field flows, Qp.

This facility is optional and can be used by clicking on the specific icon 

, after the water balance calculation. It proposes a set of priorities for irrigation of all the fields linked to a pumping station. If the farm manager decides to take the software's advice, irrigation will be halted in some fields. For the solid set system, the current sector will have to be terminated, and irrigation will resume on the following sector. This interruption must be entered in the data windows provided; the length of the interruption and the cause (energy, etc.) should be noted. It will be taken into account as well as any other interruption in the “bilan des arrêts de l’irrigation” (i.e. irrigation interruption summary) routine. Likewise, the centre pivot will be stopped on its position.

If a manager opts for this module, there are two types of decisions to be taken:
- Do not start irrigation in some fields
- Stop irrigation in others.

Systematic advice, based on water balance modelling, and optional advice, based on computation of the field classification will be displayed in two separate tables. For easy identification, the fields for which the water balance was calculated on the day in question will appear in red in the ranking table.

5. Software Description

5.1. General (fig. 6)

This software can address any irrigation system, without questioning its core concept.
The amount of water to be applied is calculated automatically or, on request, over periods of time defined by the user. Rainfall, evapotranspiration, crop coefficient and equipment efficiency are taken into account by the procedure to carry out the field water balance.
The software provides help:

- For the choice of fields to be irrigated as a priority
- For calculating the end-of-irrigation date.

For advice and syntheses, all the annual irrigation parameters are stored in different tables. They provide a clearer idea of what has happened over the irrigation year, thereby enabling better subsequent water use.

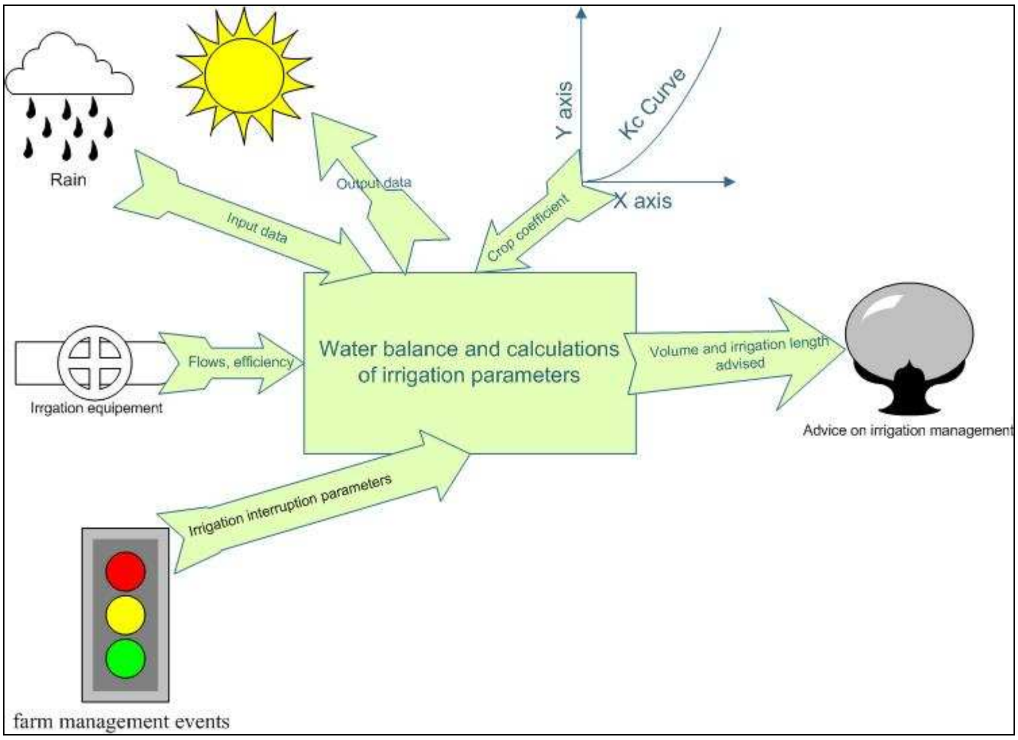


Figure 6: Software general diagram

5.2. Opening screen (fig. 7)

This fly window appears while users are waiting for connection to the database and for the software to open. It disappears automatically or by clicking on it.

Figure 7: The opening screen

5.3. Dashboard (figs. 8 and 9)

The dashboard enables easy access to all parts of the application (figure 8).
As the number of facilities is large, they are arranged under different headings, routine use and advanced use (fig. 9):

5.3.1- Routine use (click on "Opérations courantes" thumb index to display):

- Beginning of cycle
- Displaying advice
- Inputting irrigation interruptions
- Displaying advice after rainfall
- Manual inputting of the end of irrigation cycle

5.3.2- More advanced use (click on "Analyses et paramètrages du système" thumb index to display):

- Cycle management parameters
- Inputting of cropping coefficients
- Ranking of the fields to be irrigated
- Graph of water balance parameters,
- Displaying of water balance data

5.3.2.1. Overviews

- Assessment of end of irrigation parameters
- Synthesis of cumulative data
- Manual water balance computation (after the event)

5.3.2.2. Data management

- ➢ External data
  - Rainfall records
  - Climatological data necessary for evapotranspiration assessment.
- ➢ Basic data for farm representation
  - Management of irrigation equipment (field installation)
  - Field data management (all agronomic parameters relative to field and harvest management)
  - Pumping stations
  - Types of ratoons

5.3.2.3. Database management tools

- Background
- Repairing (automatic repairing of database indexes)

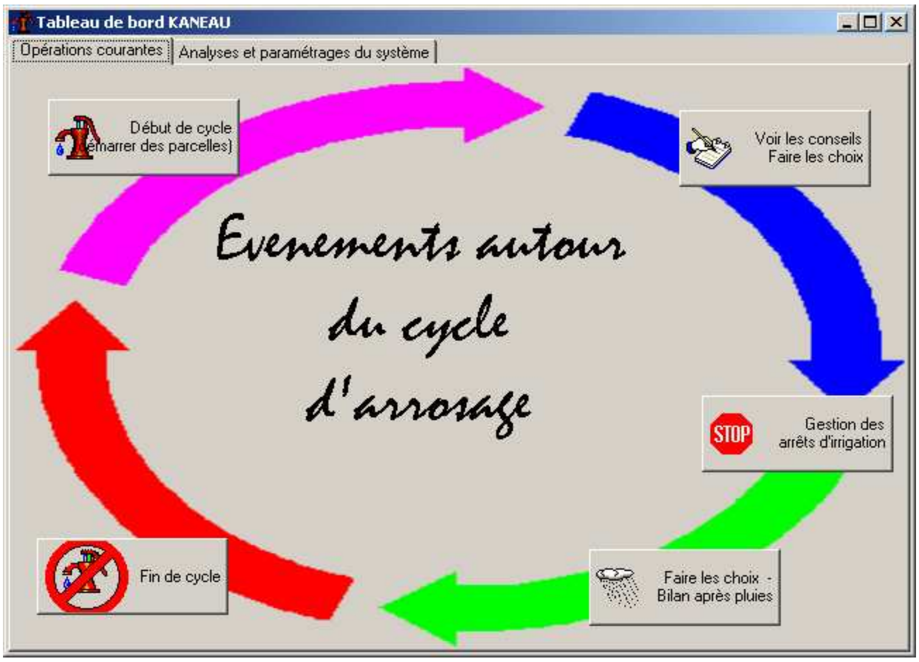


Figure 8: Dashboard - routine operations

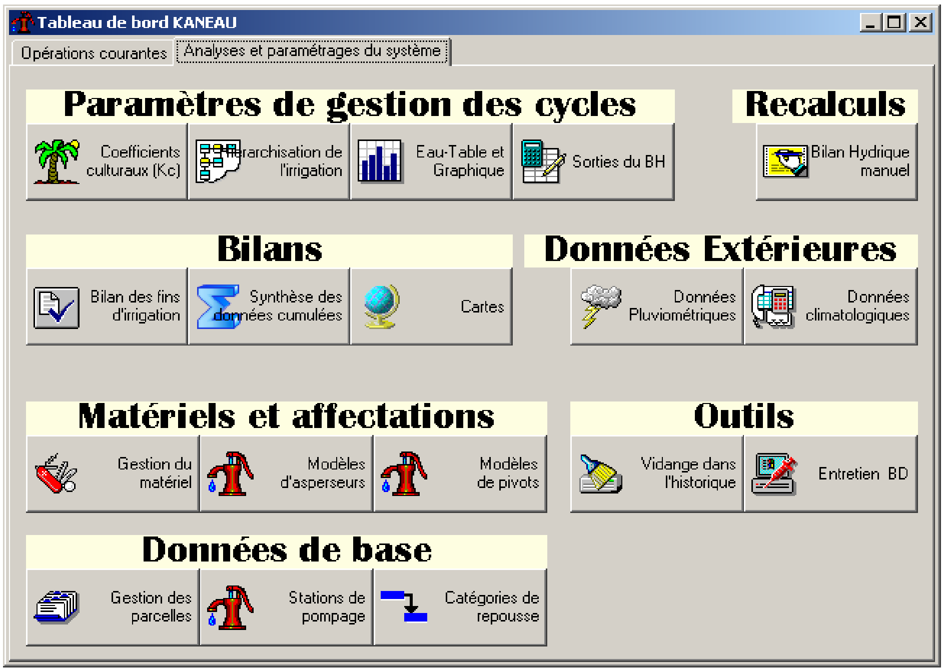


Figure 9: Dashboard - Analysis

Clicking on one of these thumb indexes launches the individualized tasks.

5.4. Cycle start-up (fig. 10)

This involves manually inputting data required to start the cycle and for the various calculations related to the preceding cycle.

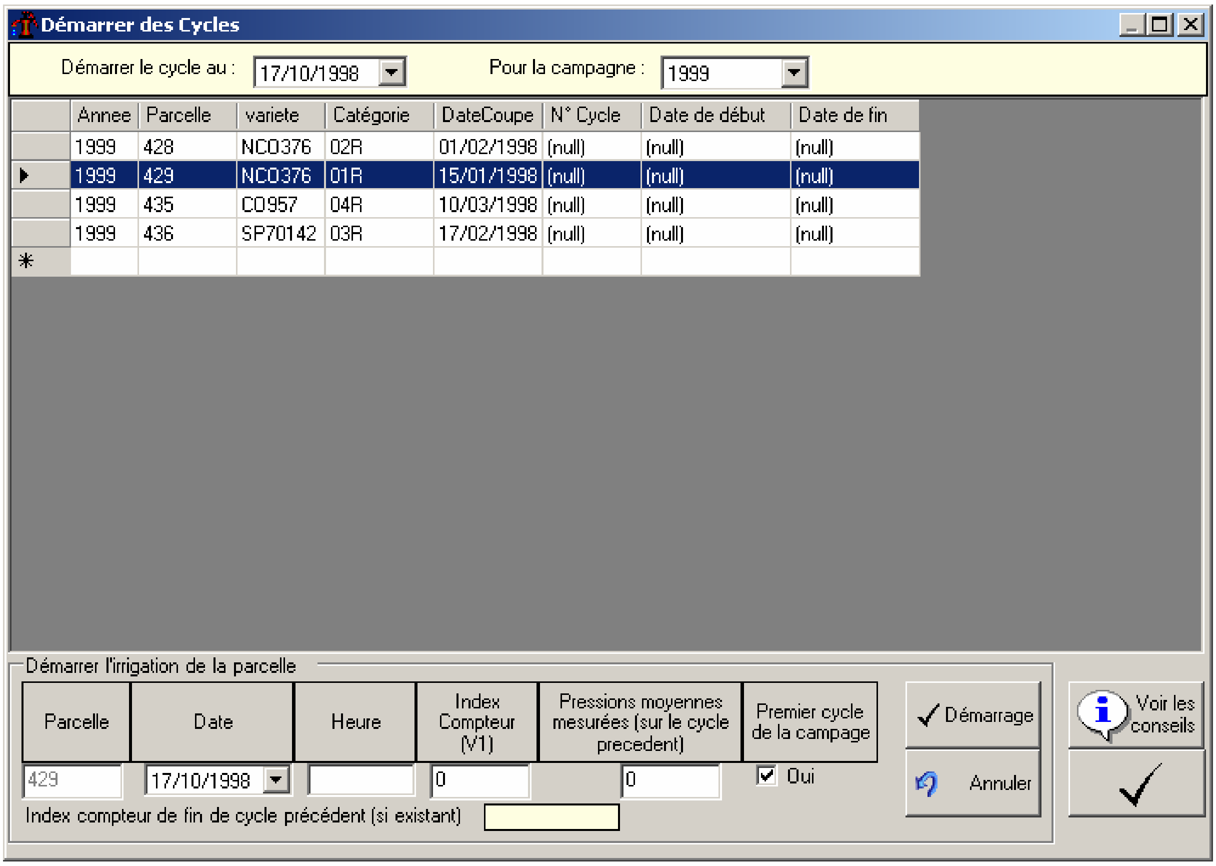


Figure 10: Cycle start-up

The design of this data window sets the conceptual layout of all the other windows. All data windows are similarly read from top to bottom.

The upper part of the window (yellow banner) is used to select the cycle start date, and the year of the harvest season. Then, in the upper greyish section of the data grid, there appears the list of all the fields ready to be irrigated on that date. The field to be irrigated is selected by clicking on the column to the left of the "Année" column. The data are then posted in grid at the bottom of the screen to be modified at the user's convenience.

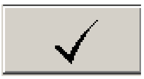
Note: when the harvest season spans two years (northern hemisphere), the year of the harvest will be that of the end-of-season harvests. For example: a field harvested in November 2002 is noted "2003 harvest", a field harvested in March 2003 is noted "2003 harvest".

The lower section is used to input cycle start-up data: the date and time irrigation begins, average pressures if available (to calculate the amount applied), measured on the preceding cycle, and the flow meter index to calculate the amount.

Validates entries,

Cancels entries

Authorizes access to the screen displaying all the advice that has just been computed



Closes the window.

5.5. Displaying and processing irrigation advice (fig. 11)

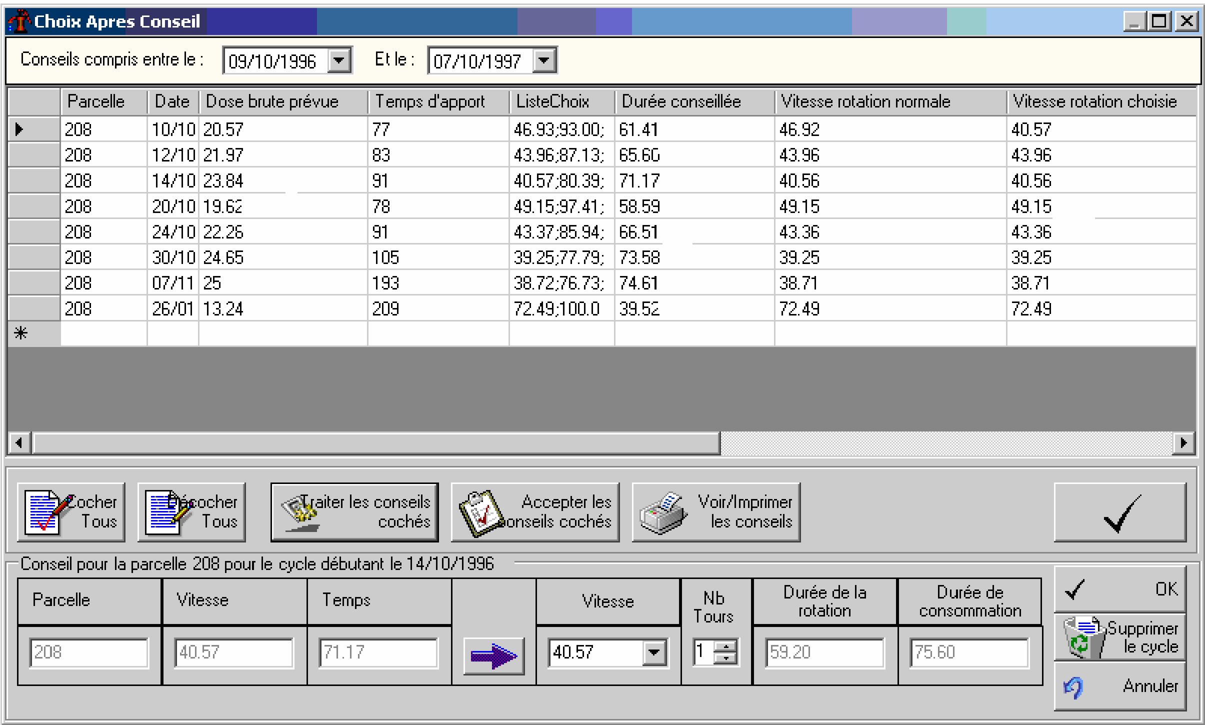


Figure 11: Displaying and processing advice

This module enables the user to consult the irrigation advice generated by the application and make decisions in accordance with that advice. This list is printable.

The upper section of the window is used to select the period. Once that is done, the list displays all the advice for that period. The user can then select a single piece of advice to display details and input any desired values. The user can also select several items of advice and click on the “*Accepter tous les conseils cochés* ” button to validate calculation by the software.

In the lower section, which displays the details, the blue arrow is used to accept the advice and the two black arrows to convert time into the amount of water, and conversely.

<u>5.6. Inputting irrigation interruptions (fig. 12)</u>

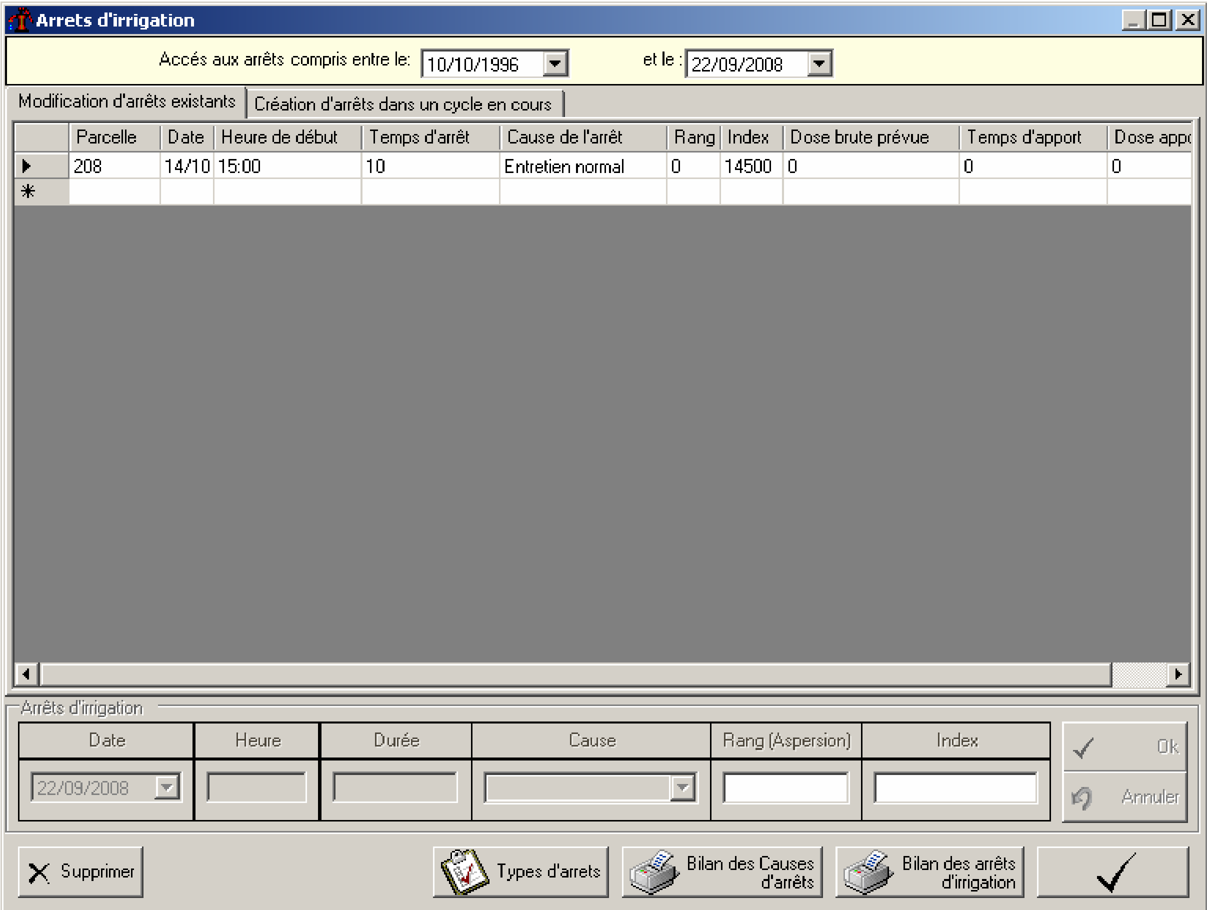


Figure 12: Inputting irrigation interruption parameters

All events related to irrigation interruptions are inputted here. These interruptions may be of different types:

- those related to farm management (cropping practices, upkeep, etc.)
- exceptional interruptions, linked to breakdowns or equipment breakage
- interruptions due to rain which may or may not lead to a change in the water balance calculation and new advice for the amounts of water to be applied after rainfall.

The interruption date is entered in the pull-down calendar. Underneath, two thumb indexes ("Modification d'arrêts existants" and "Création d'arrêts dans un cycle en cours") can be used either to modify an irrigation interruption already entered, or create a new one. Once that choice has been made, a list displays fields for which a cycle is under way, or the interruptions already recorded for the day in question.

The lower section is used to enter details of the information relative to the interruption.

The water meter index and the irrigation sector number needs to be indicated if users wish to compute a post-rainfall water balance.

This data window also provides access to a statement providing a recap of irrigation interruptions.

5.7. Displaying and processing post-rainfall advice (fig. 13)

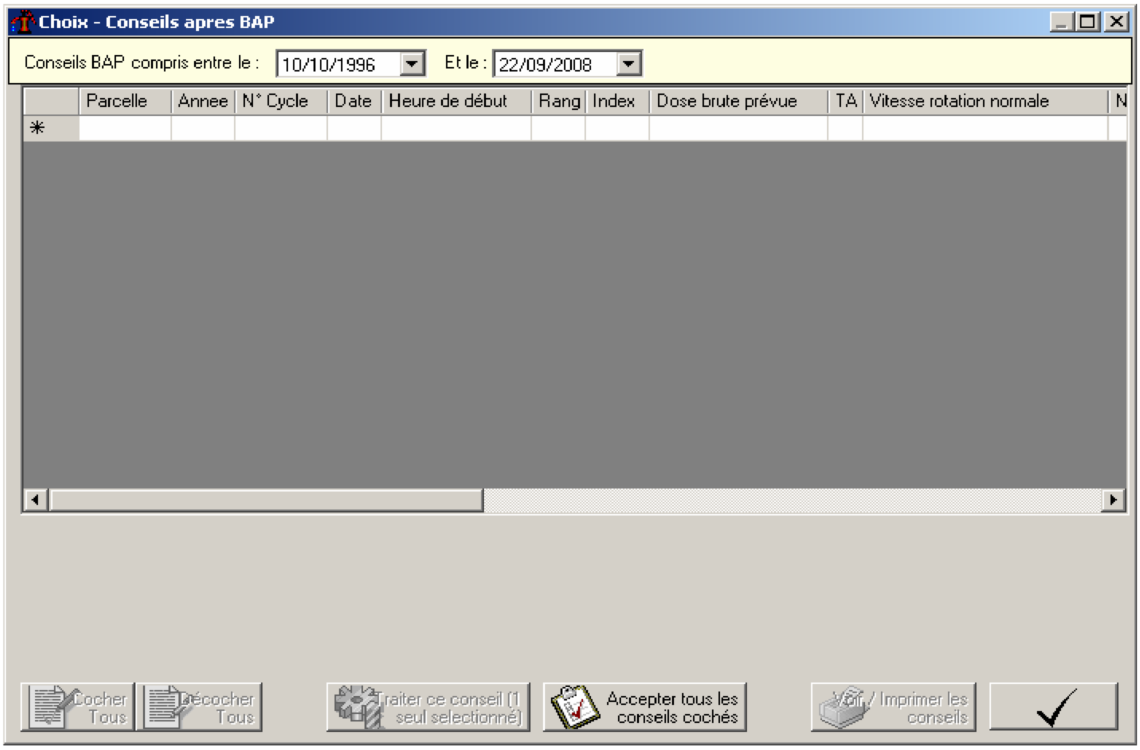


Figure 13: Displaying and processing post-rainfall advice

Information displayed in this data window is similar to that for start-of-cycle advice.

5.8. End-of-schedule data inputting (fig. 14)

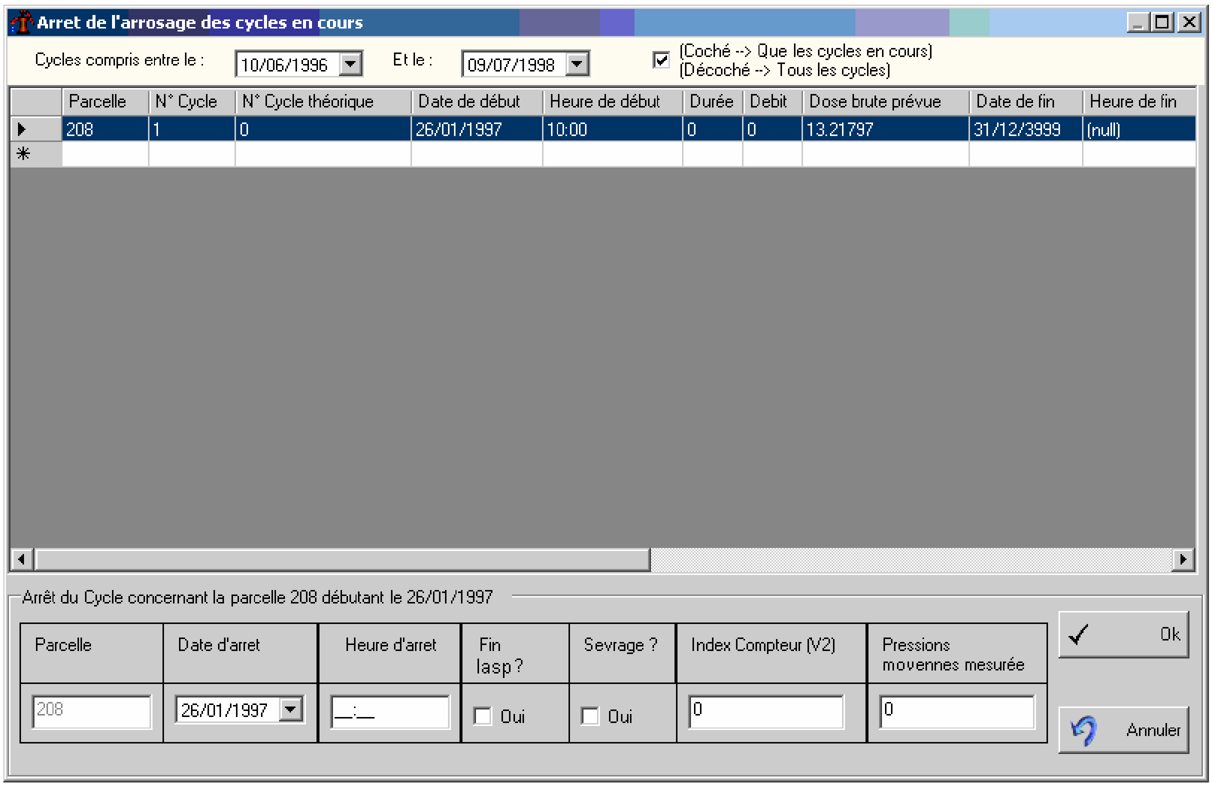


Figure 14: End-of-schedule data inputting

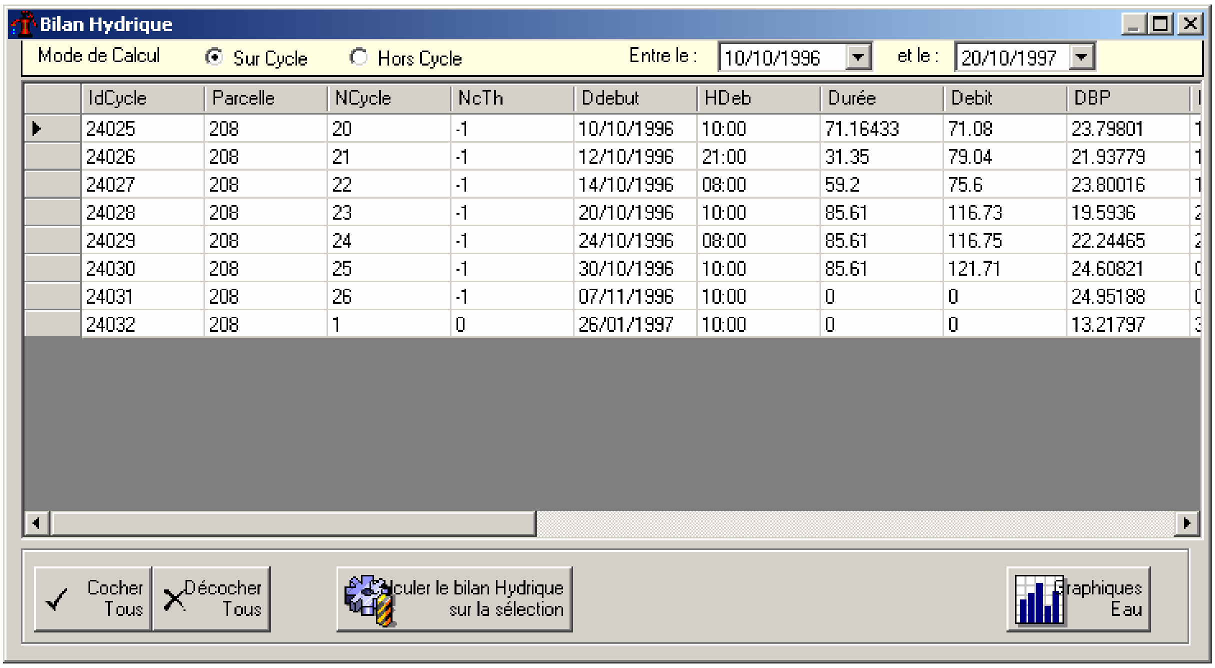
This screen is used to input information relative to the end of irrigation. This does not correspond to the end of a cycle, but to the moment when irrigation time is over (Fn date in figure 3). The date and time irrigation ends are indicated, and also whether this is the end of an irrigation season before or after rainfall.

If this irrigation cycle is the last just before the rainy season, the “Fin Iasp” icon should be ticked.

If this irrigation cycle is the last before drying off, preceding the harvest, the “Sevrage?” icon should be ticked.

The software will then compute and display certain data summaries.

5.9. "Optional" water balance (fig. 15)



IdCycle	Parcelle	NCycle	NcTh	Ddebut	HDeb	Durée	Debit	DBP
24025	208	20	-1	10/10/1996	10:00	71.16433	71.08	23.79801
24026	208	21	-1	12/10/1996	21:00	31.35	79.04	21.93779
24027	208	22	-1	14/10/1996	08:00	59.2	75.6	23.80016
24028	208	23	-1	20/10/1996	10:00	85.61	116.73	19.5936
24029	208	24	-1	24/10/1996	08:00	85.61	116.75	22.24465
24030	208	25	-1	30/10/1996	10:00	85.61	121.71	24.60821
24031	208	26	-1	07/11/1996	10:00	0	0	24.95188
24032	208	1	0	26/01/1997	10:00	0	0	13.21797

Figure 15: Optional water balance

The user can request a new specific simulation of the water balance depending on the information entered in the "traitement des conseils" (advice processing) section. It is thus possible to perform a simulation outside the current cycle without affecting it. The water balance can be calculated either on the cycle or outside the cycle (outside cycle: between two irrigation operations). If working on the cycle, the cycle should be indicated in the list. If working outside the cycle, choose "date de début" (start date), "date de fin" (end date) and "numéro de parcelle" (field number). These results can be printed.

5.10. Adjustment of the Kc crop coefficient (fig. 16)

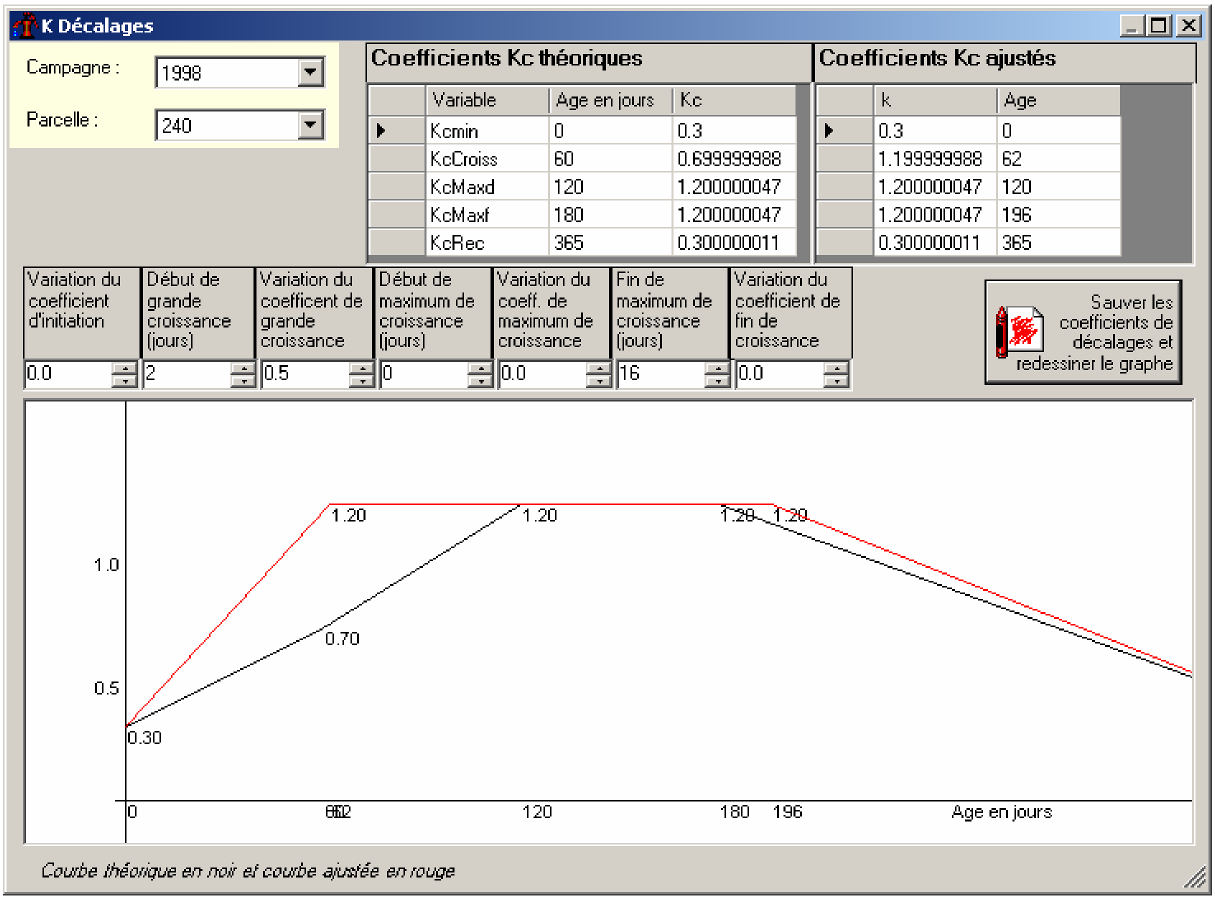


Figure 16: Kc coefficient adjustment screen

During water balance computation, actual evapotranspiration is calculated according to climatic and pedological factors, and according to the age of the sugarcane which corresponds to a stage of growth. A crop coefficient, Kc, corresponds to that stage of growth. However, when a new irrigation cycle is launched, the stage of growth and consequently the Kc coefficient may not necessarily correspond to the foreseen one; this frequent discrepancy can be attributed either to adverse climatic conditions or to incorrect application of crop cultivation techniques (e.g. late fertilisation, insufficient irrigation, poor weeding, etc.) likely to have delayed growth. The values of this parameter can easily be changed by the software. This facility is of interest not only for farm management but also for research, by facilitating the testing of variations in irrigation conditions.

This screen is used to input the value of this parameter to be taken into account for the different fields, with its validity dates. Each change in value is transferred to the graph, so the shape of the curve provides a idea of the crop's yearly water requirements.

5.11. Water balance graph display (fig. 17)

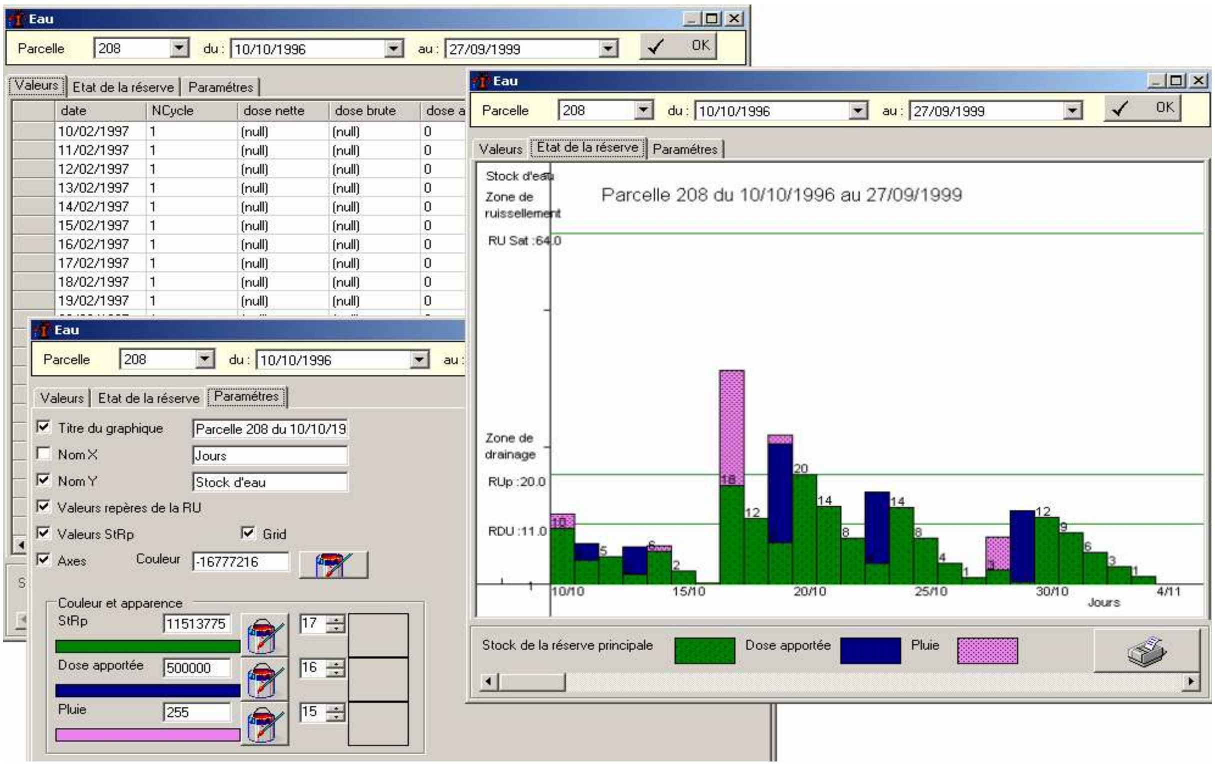


Figure 17: Representation of changes in a few water balance terms

This window graphically displays changes in all the terms of the water balance in a field. The upper section (yellow banner on upper left) is used to choose the field and the dates between which the water balance is to be calculated.

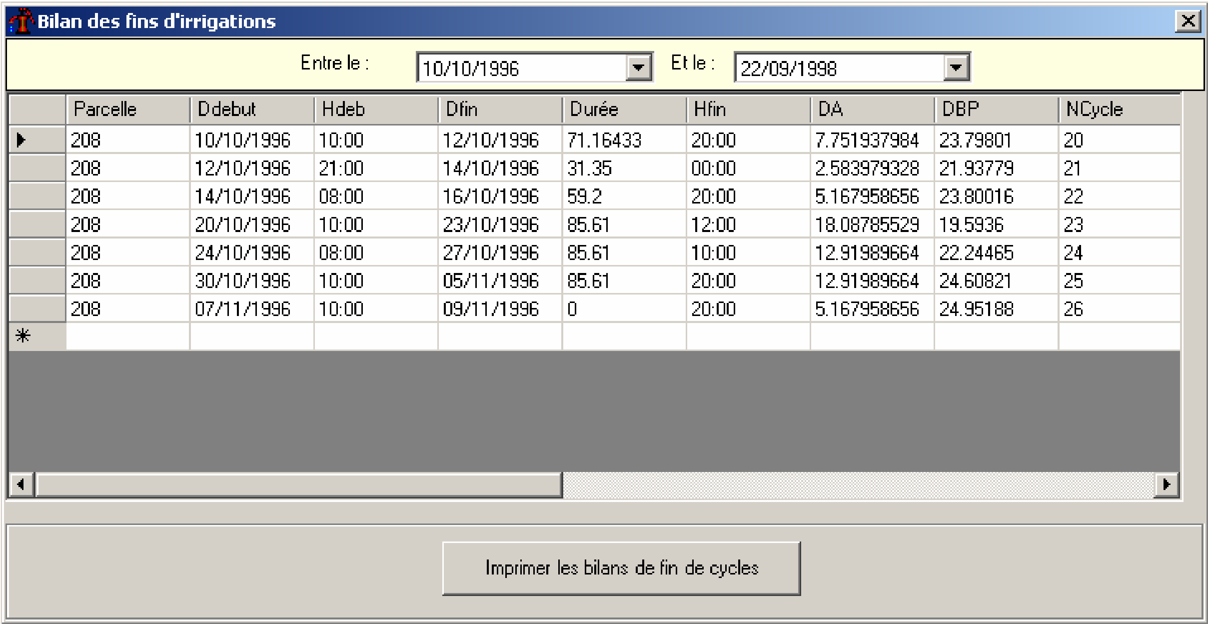
5.12. Water balance editing (fig. 18)

Figure 18: Data inputting for water balance editing

This screen is used to enter the field number and the dates between which a statement of water balance parameters is required. Merely select the values in the calendars and in the pull-down list.

5.13. End of irrigation cycle summaries (fig. 19)

This screen provides a recap of end-of-cycle water balances over the interval between the dates entered in the banner. Merely choose the dates, the screen updates automatically



Bilan des fins d'irrigations

Entre le : 10/10/1996 Et le : 22/09/1998

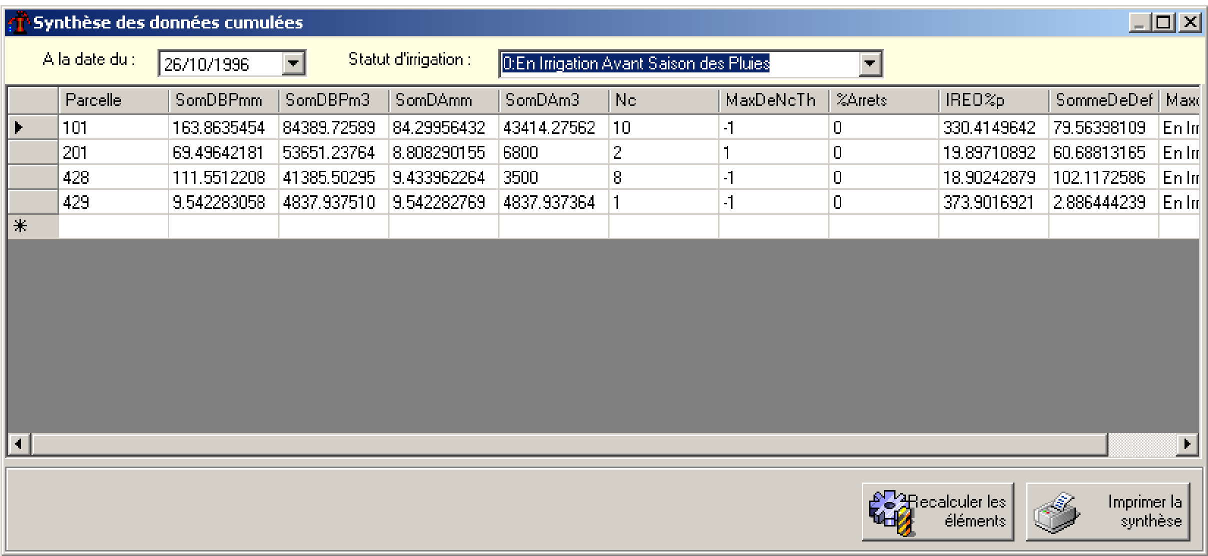
Parcelle	Ddebut	Hdeb	Dfin	Durée	Hfin	DA	DBP	NCycle
208	10/10/1996	10:00	12/10/1996	71.16433	20:00	7.751937984	23.79801	20
208	12/10/1996	21:00	14/10/1996	31.35	00:00	2.583979328	21.93779	21
208	14/10/1996	08:00	16/10/1996	59.2	20:00	5.167958656	23.80016	22
208	20/10/1996	10:00	23/10/1996	85.61	12:00	18.08785529	19.5936	23
208	24/10/1996	08:00	27/10/1996	85.61	10:00	12.91989664	22.24465	24
208	30/10/1996	10:00	05/11/1996	85.61	20:00	12.91989664	24.60821	25
208	07/11/1996	10:00	09/11/1996	0	20:00	5.167958656	24.95188	26

Imprimer les bilans de fin de cycles

Figure 19: End of irrigation cycle summary

5.14. Synthesis of cumulative data (fig. 20)

At the end of each irrigation period, the operator is provided with a synthesis of a few relevant parameters. They should provide a clearer picture of the events occurring over the irrigation period and, where needed, enable changes to some processes.
This table can only be edited at the end of an irrigation period; either at the end of irrigation before the rainy season (Iasp end) or at the last irrigation just before drying-off (Ipsp end)
The user is simply required to input, via the yellow banner, the date and period of irrigation (Iasp, Ipsp, drying-off) for which a synthesis of the cumulated data is wanted.



Synthèse des données cumulées

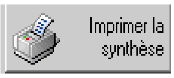
A la date du : 26/10/1996 Statut d'irrigation : 0:En Irrigation Avant Saison des Pluies

Parcelle	SomDBPmm	SomDBPm3	SomDAmm	SomDAm3	Nc	MaxDeNcTh	%Arrets	IREO%p	SommeDeDef	Max
101	163.8635454	84389.72589	84.29956432	43414.27562	10	-1	0	330.4149642	79.56398109	En Ir
201	69.49642181	53651.23764	8.808290155	6800	2	1	0	19.89710892	60.68813165	En Ir
428	111.5512208	41385.50295	9.433962264	3500	8	-1	0	18.90242879	102.1172586	En Ir
429	9.542283058	4837.937510	9.542282769	4837.937364	1	-1	0	373.9016921	2.886444239	En Ir

Recalculer les éléments
Imprimer la synthèse

Figure 20: Synthesis of cumulative data

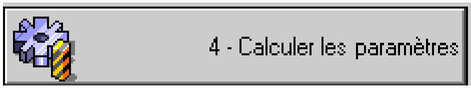
launches computation.



prints the results.

5.15. Decision-making aid in the event of a water shortage (figs. 21 and 22)

The screen in figure 21 is used to input the parameters needed to calculate ranking: date, pumping station code and its discharge rate.
The user is first required to input the date on which the fields must be sorted, the number of the pumping station and its actual discharge rate. This last value is totally dependent on the energy supplied by the factory.



launches computation and the result is displayed on the right-hand side of the screen.

displays the printable table. The printed table provides some additional information, such as the soil's water reserve, for better evaluation of the computed advice.

is a facility using a GIS to display field ranking on the complex map (fig. 22).

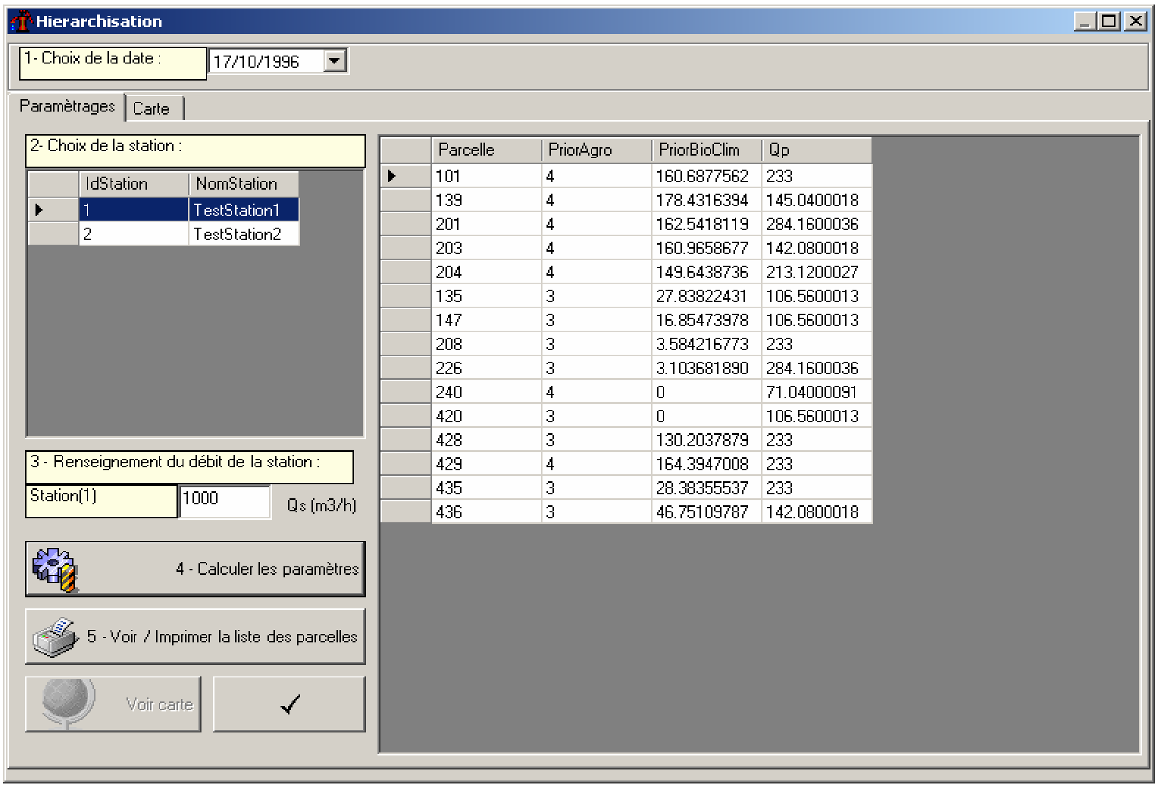


Figure 21: Decision-making screen in the event of a water shortage

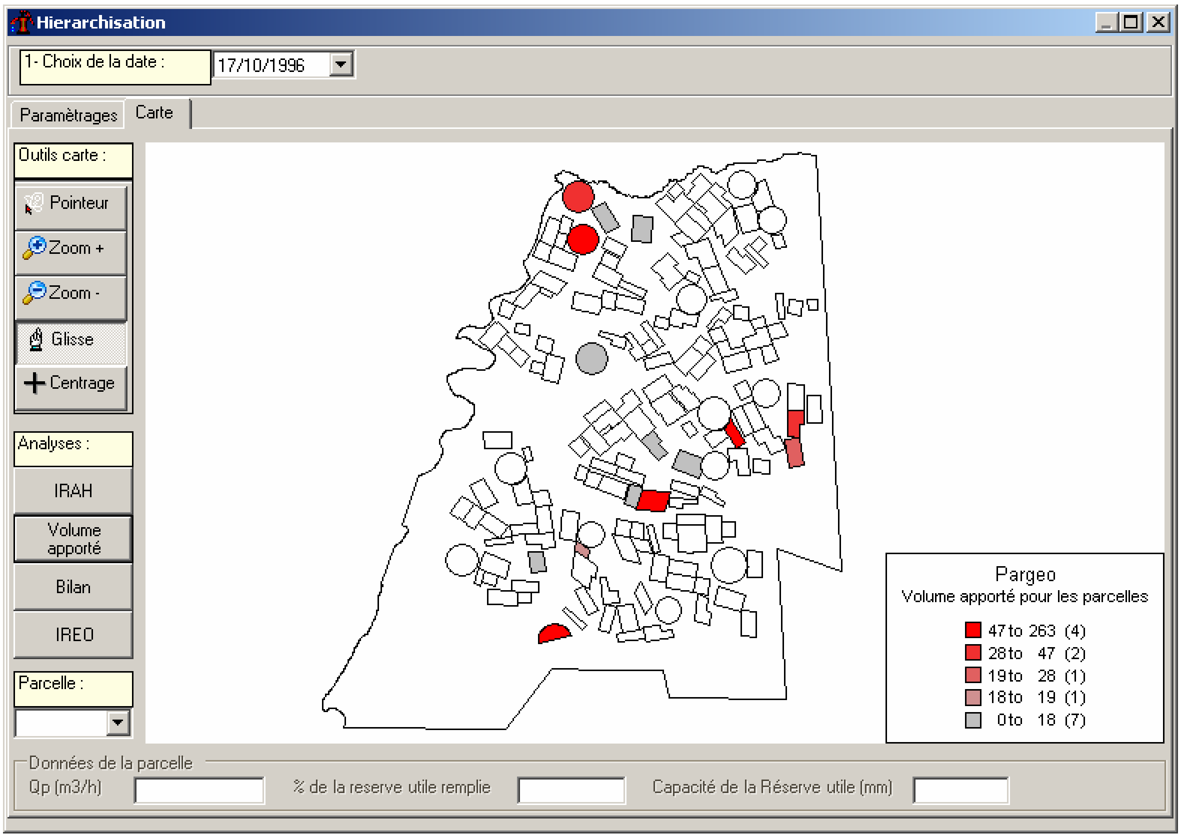


Figure 22: – Mapping of field ranking

5.16. Equipment management (fig. 23)

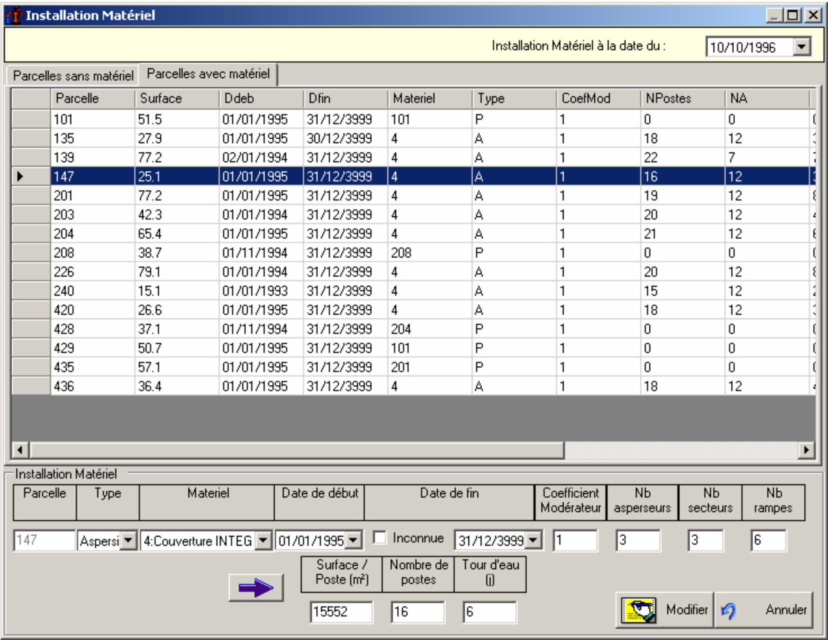


Figure 23: Equipment management

This screen is used to enter or, if necessary, modify information related to irrigation system installation.

This screen is divided into three parts. The first one is the yellow banner in which the user inputs the current date. The central section has two grids displayed using two thumb indexes, “Parcelles sans materiel” and “Parcelles avec materiel”. The first gives the list of fields with no equipment yet defined; it enables inputting of all the parameters related to new equipment. The second is used to show all fields for which all equipment is precisely described, and to change them if necessary.

In the lower section, all information specific to the irrigation equipment installed is entered (for sprinklers: number of units, NA, NR).

Modifies any wrong input.

Cancels this action and returns to the previous screen.

5.17. Pumping stations (fig. 24)

This screen is used solely to input information about the pumping stations (name only).

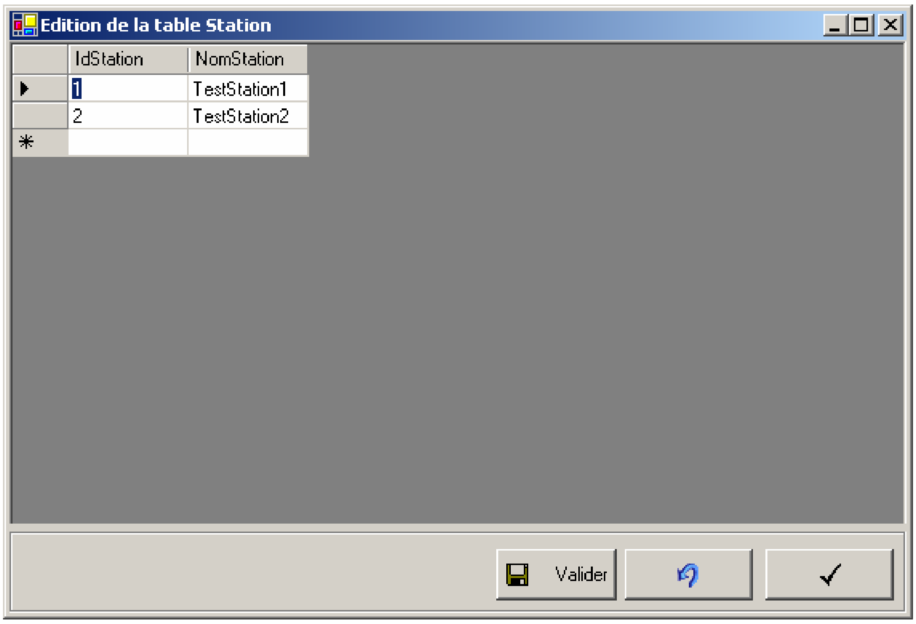
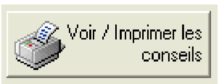


Figure 24: Pumping station descriptions

6. Output tables (fig. 25)

All the software's output tables have the same presentation with the title and CIRAD logo at the top, the date and the page number at the bottom.
The images shown below are copies of pre-printing screen displays for the output tables. That is why they are not full size.



Prints the various tables

The pre-print screen has the following tool bar

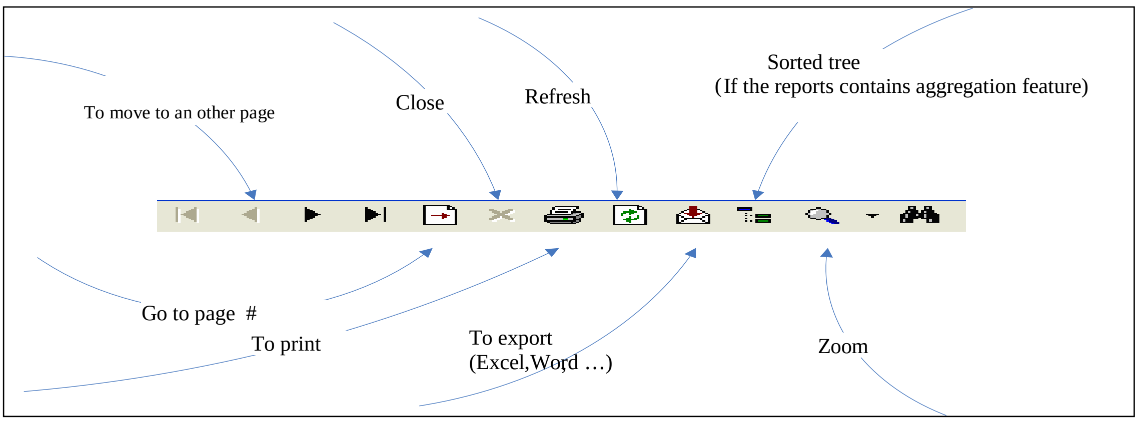
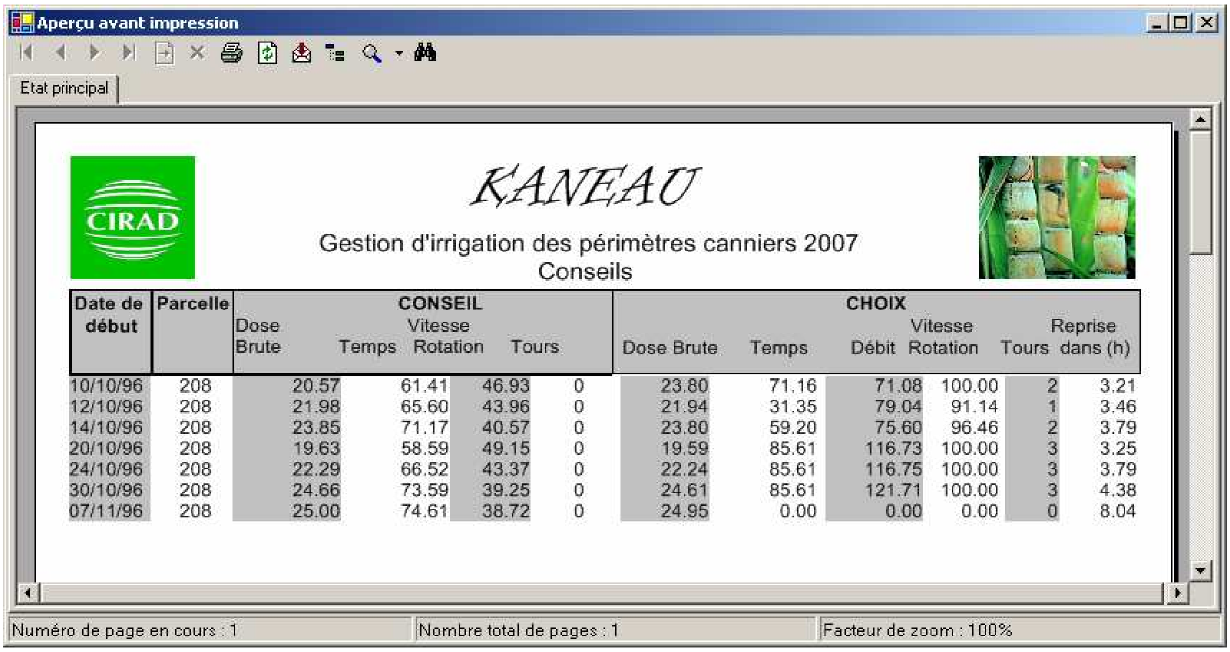


Figure 25 - Tool bar of the pre-print screen

6.1. The first irrigation advice (fig. 26)



Date de début	Parcelle	CONSEIL Dose Brute	Temps	Vitesse Rotation	Tours	CHOIX Dose Brute	Temps	Débit	Vitesse Rotation	Tours	Reprise dans (h)
10/10/96	208	20.57	61.41	46.93	0	23.80	71.16	71.08	100.00	2	3.21
12/10/96	208	21.98	65.60	43.96	0	21.94	31.35	79.04	91.14	1	3.46
14/10/96	208	23.85	71.17	40.57	0	23.80	59.20	75.60	96.46	2	3.79
20/10/96	208	19.63	58.59	49.15	0	19.59	85.61	116.73	100.00	3	3.25
24/10/96	208	22.29	66.52	43.37	0	22.24	85.61	116.75	100.00	3	3.79
30/10/96	208	24.66	73.59	39.25	0	24.61	85.61	121.71	100.00	3	4.38
07/11/96	208	25.00	74.61	38.72	0	24.95	0.00	0.00	0.00	0	8.04

Figure 26 - Start-of-cycle advice

This table summarizes the amount of water computed at the beginning of each cycle. The user's choice is also displayed. If this choice has yet to be made, the box remains empty. Furthermore, users can also enter the choice manually, and it is automatically entered in the software.

6.2. Field ranking under water shortage conditions (fig. 27)

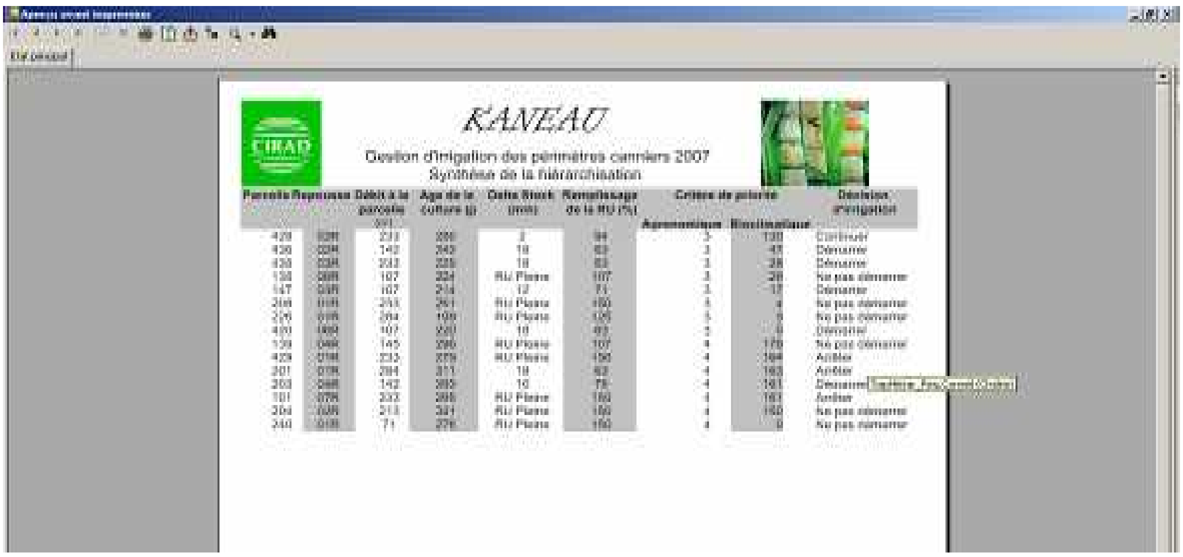


Figure 27: Recap of plots to be irrigated as a priority

This table displays the ranking of plots to be irrigated and in which irrigation is to be stopped depending on available water flow. It also displays information on the water reserve in the fields.

6.3. Post-rainfall irrigation table and advice

This table displays all advice computed after rainfall. The user's choice is also shown. If this choice has not yet been made, the box is empty; the user can then enter it manually for subsequent inputting into the software.

6.4. Irrigation interruptions table (fig. 28)

This table displays all the irrigation interruptions over a cycle length and assesses their relative importance. These interruptions are sorted by type: breakages, maintenance, farming practices, rainfall.
It can be modified at the user's request.

Parcelles	N° Cycle	Causes	Temps d'arrêts (h)
208	22	Entretien normal	10.00
		Total à la parcelle	10.00

Figure 28: Summary of irrigation interruptions

6.5. Water balance table (fig. 29)

This table displays all the hydraulic parameters computed by the water balance model. These parameters describe the different hydraulic conditions in the fields during irrigation.

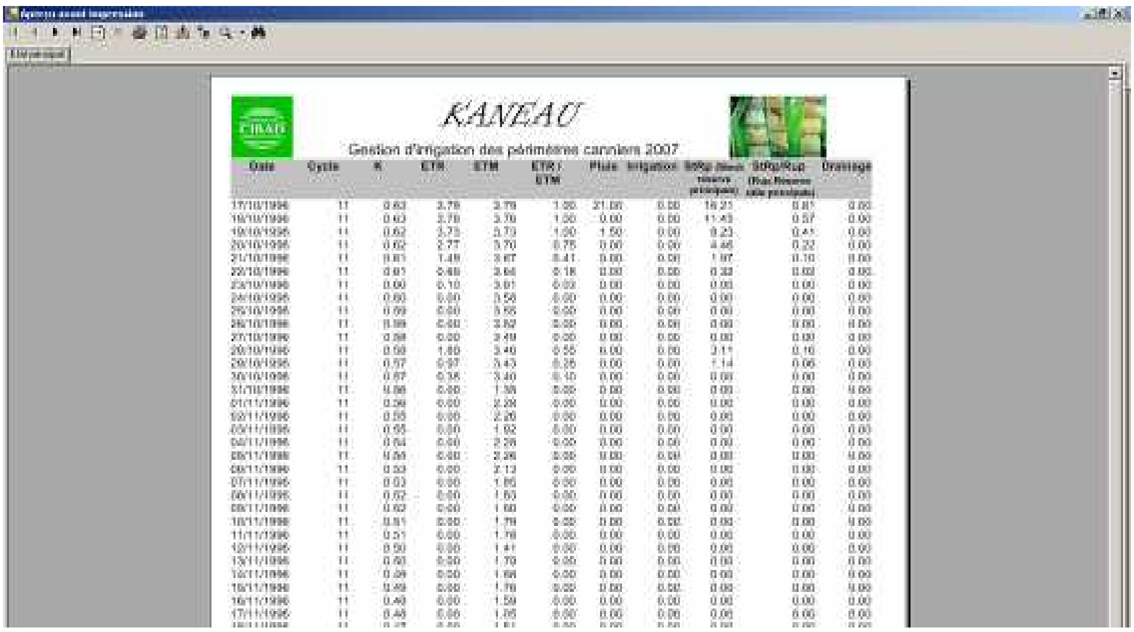


Figure 29 : Summary of field hydraulic parameters

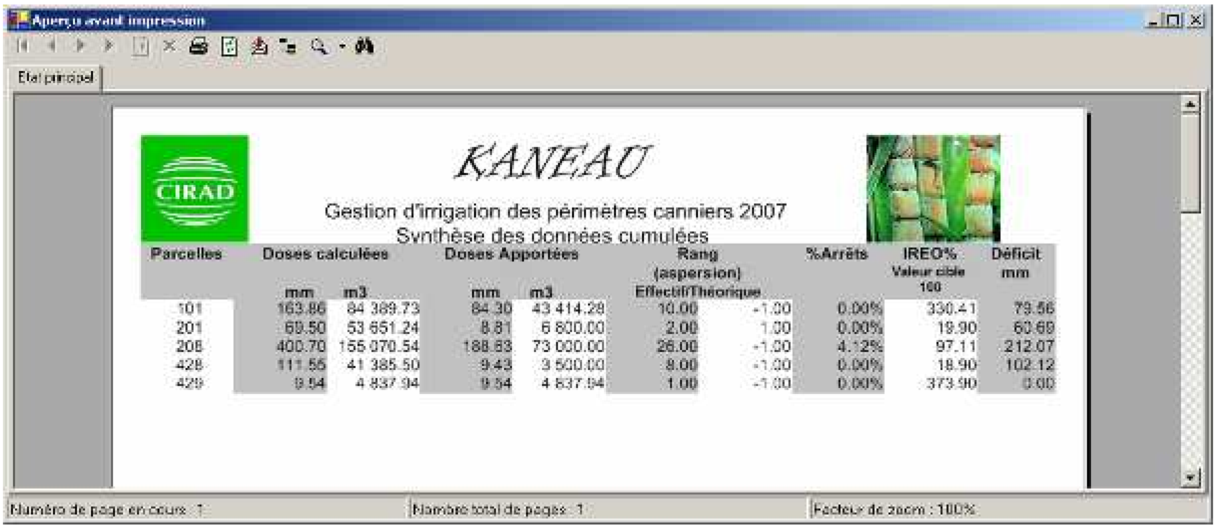
6.6. End-of-irrigation table (fig. 30)

This table summarize the main relevant irrigation parameters at the end of each cycle.

Figure 30: End of irrigation summary

6.7. Cumulative data table (fig. 31)

This table is edited at the end of each irrigation period, i.e. at the end of the dry season (Iasp) and on the last irrigation just before drying-off (Ipsp). It displays in a clear table some of the most synthetic information that enables a relevant analysis of the irrigation season.


Aperçu avant impression

Etat principal

KANEAU

Gestion d'irrigation des périmètres canniers 2007

Synthèse des données cumulées

Parcelles	Doses calculées mm	Doses calculées m3	Doses Apportées mm	Doses Apportées m3	Rang (aspersion) Effectif/Théorique		%Arrêts	IREO% Valeur cible 100	Déficit mm
101	163.86	84 389.73	84.30	43 414.28	10.00	-1.00	0.00%	330.41	79.56
201	69.50	53 651.24	8.81	6 800.00	2.00	1.00	0.00%	19.90	60.69
208	400.70	155 070.54	188.83	73 000.00	26.00	-1.00	4.12%	97.11	212.07
428	111.55	41 385.50	9.43	3 500.00	8.00	-1.00	0.00%	18.90	102.12
429	9.54	4 837.94	9.54	4 837.94	1.00	-1.00	0.00%	373.90	0.00

Numéro de page en cours : 1 | Nombre total de pages : 1 | Facteur de zoom : 100%

Figure 31: Summary of cumulative data

List of principal symbols and acronyms

BH: Refers to the water balance assessment

Dr : Deep percolation

DNP: Computed net amount of water

DBP: Computed gross amount of water

BsQP: Daily water requirement

DNQA: Daily nominal water discharge from the lateral

DNA: Nominal water discharge related to revolution time

TRN : Revolution running time

TA: Water application length. Where sprinklers are concerned, this is the duration of a position.

DA: Quantity of water applied

Iasp: Irrigation before the rainy season and post-harvest (northern hemisphere).

Ipsp: Irrigation from the end of the rainy season to drying-off before harvest (northern hemisphere).

DTC: Total cycle length

IREO%: This index characterises the quality of irrigation processing.

NA : Number of sprinklers

NR : Number of laterals.

ETc : Crop evapotranspiration under standard conditions (mm d^{-1})

ETc.adj : Crop evapotranspiration under non-standard conditions (mm d^{-1})

R : Rain

Irr : Irrigation

SAW : Soil available water

Dr : Drainage