

FOURTY YEARS OF CONTINUOUS MONITORING OF AGRICULTURAL DRAINAGE IN WESTERN FRANCE

QUARANTE ANS DE SUIVI CONTINU DU DRAINAGE AGRICOLE A L'OUEST DE LA FRANCE

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ABSTRACT

The experimental drainage system of the Jaillièr (northwestern France) was set up in a french national context of drainage. The starting point for the Jaillièr experiment is in 1987, in which drainage and runoff water are collected separately. Ten plots are equipped for the collection of drainage and/or runoff water, with areas ranging from 0.34 to 1.08 hectare. One plot kept undrained allows for the measurement of saturation runoff, which predominates in this pedoclimatic environment. The measurement of water flows is carried out on triangular overflow, with a time step of one hour.

In 2026, nearly forty years after the acquisition of the first experimental data, the hydraulic measurements of the Jaillièr shed particular light on the long-term effects of drainage in agricultural plots. In the pedoclimatic context of western France, rainfall supplies water to drainage and runoff networks mainly in the winter. Drainage or runoff may occur in the spring and summer, but only one year out of three on average.

From the beginning to the end of a season called the intense drainage season (IDS), water flow in drainage and/or runoff networks is quasi-continuous. During this period, the portion of rainfall evacuated through drainage and/or runoff networks is used to compute the coefficient of restitution (CR_{SDI}).

With these data it is possible to assess the average response of drainage and runoff networks to rainfall in the pedoclimatic context of the Jaillièr. Each plot gives an individual hydraulic response influenced by interactions with adjacent plots and with the geologic context, composed of cracked schists.

Long-term setups such as ours help addressing changes in drainage and runoff regimes over the long term and provide data to assess the long-term consequences of farming practices and the effects of climate change under defined environmental conditions (soil, climate).

Keywords : Agricultural drainage; Water flow; Runoff networks; Agricultural practices; Environmental conditions.

RESUME

Le système expérimental de drainage de la Jaillièr (nord-ouest de la France) a été créé dans le cadre national français du drainage. L'année 1987 était le point de départ de l'expérience de la Jaillièr, où les eaux de drainage et les eaux de ruissellement ont été collectées séparément. Dix parcelles ayant une superficie comprise entre 0,34 et 1,08 hectare, étaient équipées de collecter des eaux de drainage et/ou de ruissellement. Une parcelle non drainée permettait de mesurer le ruissellement par saturation, qui prédominait dans cet environnement pédoclimatique. Les débits étaient mesurés à l'aide de déversoirs triangulaires, avec un pas de temps d'une heure.

En 2026, près de quarante ans après l'acquisition des premières données expérimentales, les mesures hydrauliques de la Jaillièr apportent un éclairage particulier sur les effets à long terme du drainage sur

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les parcelles agricoles. Dans le contexte pédoclimatique de l'ouest de la France, les précipitations alimentent les réseaux de drainage et de ruissellement principalement en hiver. Le drainage ou le ruissellement peuvent se produire au printemps et en été, mais en moyenne une année sur trois seulement. Du début à la fin d'une saison appelé «saison de drainage intense» (IDS), l'écoulement d'eau dans les réseaux de drainage et/ou de ruissellement est quasi-continu. Au cours de cette période, on calcule le coefficient de restitution (CRSDI) à l'aide d'une partie des précipitations évacuée par ces réseaux de drainage.

A la lumière de ces données, il est possible d'évaluer la réponse moyenne des réseaux de drainage et de ruissellement aux précipitations dans le contexte pédoclimatique de la Jaillière. Chaque parcelle présente une réponse hydraulique propre, influencée par les interactions avec les parcelles adjacentes et par le contexte géologique, constitué de cristallins fissurés.

Les programmations à long terme tels que celles-ci permettent d'étudier l'évolution des régimes de drainage et de ruissellement longtemps et fournissent des données permettant d'évaluer les conséquences à long terme des pratiques agricoles et les effets du changement climatique dans le cadre des conditions environnementales bien définies (sol, climat).

Mots-clés : Drainage agricole; Ecoulement de l'eau; Réseaux de ruissellement; Pratiques agricoles; Conditions environnementales.

INTRODUCTION

At the end of the 1980s, the French Ministry of Agriculture and the Office National Interprofessionnel des Céréales (ONIC) financed the Sectors of Reference-Drainage operation, with a dual objective:

- Acquire detailed knowledge of soil hydropedological conditions at the scale of small natural regions in the French metropolitan territory;
- Provide technical references for the design and use of drainage networks in agriculture.

Complementary agronomic experiments have been decided to provide farmers with recommendations adapted to the management of agricultural plots after drainage. It is in this context that the experimental drainage system of La Jaillière (44-49) was set up, in order to test the operation of agricultural drainage through crop rotations adapted to the local context, according to two soil tillage methods (ploughing and no-till cropping techniques). The implementation of this experiment was decided in 1986, as part of a collaboration between ITCF² and Cemagref³ (which became respectively ARVALIS and INRAE).

EXPERIMENTAL OBJECTIVES

There are few field devices designed for the measurement of water flows in real time and continuously. The plots of the Jaillière are equipped for the separate collection of drainage water and runoff water. The measurement of water flows at the outlet of the plot is the key information of the experimental device of the Jaillière. The flow rates allow the calculation of water depth per unit of time (day, season, crop year).

To supplement the acquisition of references by taking advantage of the infrastructure in place, water samples are taken from the various water flows and then sent to the laboratory for analysis of solutes (nitrate, phosphorus, plant protection residues).

The experimental device planned to monitor the operation of agricultural drainage evolved from 1989 towards a goal of measuring solute transfers in connection with agricultural practices. As MP.Arlot points out in his thesis work (Arlot MP., 1999), agricultural drainage, although it modifies the hydraulics of

² ITCF : Institut Technique des Céréales et des Fourrages became ARVALIS – Institut du végétal en 2002

³ Cemagref : it became IRSTEA in 2011, then INRAE in 2020

hydromorphic soils (active drainage), proves to be a suitable tool for collecting seepage water, and therefore to identify and characterize the processes involved in solute transfers (control drainage).

Thus, in 2026, the Jailli re experimental facility made it possible to acquire nearly forty years of data on agricultural hydraulics (drainage and runoff), and about thirty-five years of data on solute transfers.

EXPERIMENTAL SETUP

The research and experimentation station of La Jailli re is located in western France, at Chapelle-Saint-Sauveur, commune of Loireauxence (44). The physical environment is typical of western France: typical bocage landscape, oceanic climate with an average annual rainfall of 725 mm, an average annual evapotranspiration (Etp) of 785 mm, and an average daily temperature of about 6 C in winter and 20 C in summer. (period 2006-2024, meteorological station of the Jailli re). The soils are hydromorphic brown soils, with a silty-clayey texture, developed on shale weathering formations. Hydromorphy is quite pronounced, with excess water manifesting itself at the surface of the soil: rapid waterlogging and saturation overland flow.

The experimental set-up at La Jailli re consists of 10 plots of agricultural size (between 0.4 and 1 hectare), with separate collection of drainage and runoff water:

- Each drained plot has an individualized drainage network (drains + collector).
- Surface runoff is collected by a runoff trap (dam placed at the bottom of the slope) specific to each equipped plot.
- The collected water is transported via a sealed pipe to a measurement chamber for the measurement of water flows.

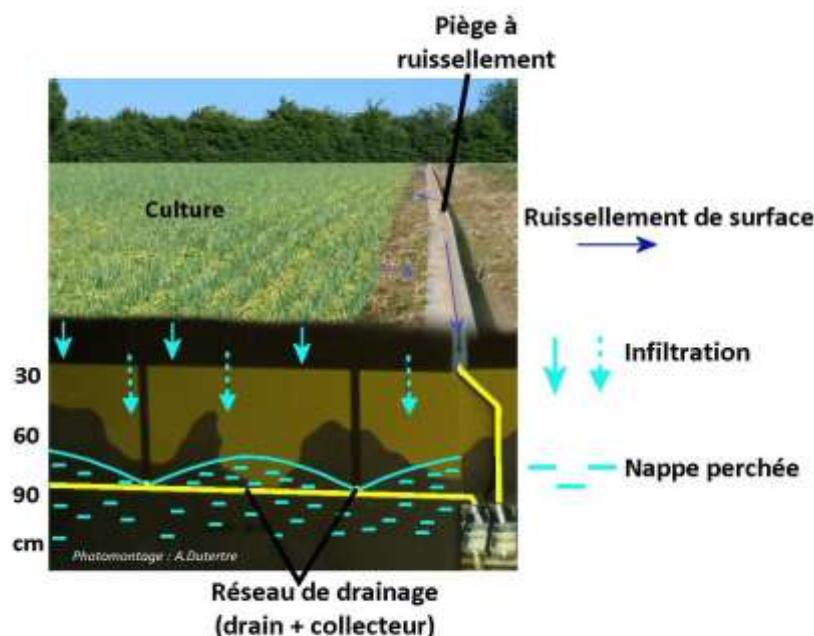


Figure 1: ORGANIZATION OF WATER COLLECTION IN THE DRAINED PLOT (A.DUTERTRE)

The plots are drained by buried pipes, with corrugated PVC drains. The diameter of the drains is 50 mm and that of the collectors 100 mm. The pipes are laid either at the trencher (opening of the trench with excavation of the earth) or at the subsoiling (passage of a tooth without excavation). The drains are laid

bare, without any coating (natural fibers or geotextile) or addition of gravel in the trenches. The establishment of the experimental plots of the Jaillièrè system was carried out in three stages:

Table 1: Year of création and characteristics of the drainage of the Jaillièrè plots

Plot	Year of drainage	Depth and installation spacing	Type of installation
3, 4, 5 & 6	1987	10 mètres / 0,80 mètre	Trencher drainer
7, 8 & 9	1981	12 mètres / 0,80 mètre	Trencher drainer
10 & 11	1991	10 mètres / 0,80 mètre	Subsoleuse drainer

From a methodological point of view, two precautions make it possible to control lateral water inflows and outflows:

- The site of La Jaillièrè is located in a plateau position, with a roadside ditch on the west side, a moat at the bottom of talweg on the southeast side and a stream on the north side. This stream, the Rai Profond, is also the natural outlet for drainage and runoff water from the subwatershed.
- The creation of a hydraulic protection between the test plots, with the construction of draining trenches in the middle of the aisles of the device. The aisles are at least 10 meters wide. A drain is laid about 1 meter deep, then gravel is added almost to the surface of the ground.

EXPERIMENTAL DATA

Meteorological data from the La Jaillièrè station have been recorded since 1982 :

- Through a weather station located to the west of the station (47°27'03.00"N - 0°58'17.60"O), referenced as ARVALIS No. 4499, from January 1982 to September 2017.
- By a weather station installed since November 2005 on the experimental device (47°27'24.24"N - 0°57'17.00"O), referenced as ARVALIS No. 4997.
- The data used for this work comes from station no. 4499 for the period from 01/01/1982 to 31/12/2005, then from station no. 4997 for the period from 01/01/2006 until now.
- The data is used on a daily scale.
- The hydrometric equipment consists of spillway basins, sensors for water level measurement and data loggers.
- The spillway tank is a hydraulic structure with a V-shaped spillway. In the Jaillièrè experiment, the spillways are thin stainless-steel blades with a V whose opening angle is 30°. The flow rate is proportional to the height of water measured upstream from the spillway (Figure 2).
- The measurement of water depth in spillway tanks is carried out using immersed ultrasonic sensors (model SND-UST 540) from 1987 to 2014, followed by pressure sensors (model CS 451) since 2014.
- The recorders are SAB600 acquisition stations from CR2M from 1987 to 2014, then CR1000 stations from Campbell Scientific since 2014.

Water heights are instantaneous measurements taken with an hourly time interval. They are stored in the recorder's memory, then collected to be converted into $L.s^{-1}.ha^{-1}$ flow rates (Table 2).

To facilitate data analysis and comparisons with rain (input data), the flows are converted into water strips (daily, monthly, annual), expressed in mm. The hourly flows ($L.s^{-1}.ha^{-1}$) and the daily water strips (mm) are archived in tables of values by crop year (period from 1 September to 31 August).

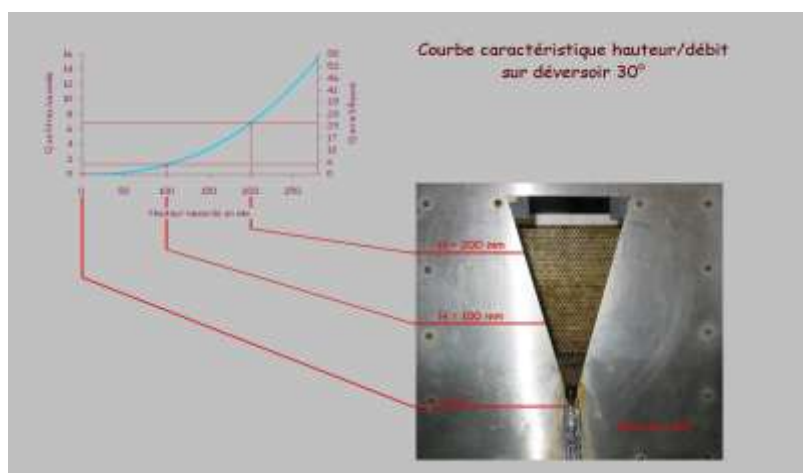


Figure 2: Operating principle and photos of overflow bins

Table 2 : Height / waterflow / waterstrip relationship

Measured water level in mm*	Flow in $L.sec^{-1}.hectare^{-1}$	Flow in $m3.hour^{-1}.hectare^{-1}$	Water blade in $mm.day^{-1}$
5	0.001	0.004	0 ;01
10	0.004	0.014	0.03
50	0.228	0.821	1.97
100	1.248	4.493	10.78
200	6.819	24.548	58.92
280	15.549	55.976	134.34

*Height measured for a contributory area of 1 hectare

DRAINAGE RECORDS AND ANNUAL TOTALS

The drainage network inflow starts when the soil water reserve is replenished and the temporary perched water table⁴ is installed. The drains are fed directly by the perched water table, itself influenced by the rainfall regime. The feeding period of the networks generally stops when the climatic demand (evapotranspiration) becomes greater than the inputs (rain), and the temporary perched water table recedes.

The annual drainage hydrography (Figure 3) is a more or less continuous sequence of drainage network inflow. Peak flows, or floods, alternate with calmer periods corresponding to phases of soil drainage, sometimes until the complete drying up of the networks.

⁴ Perched water table : corresponds to the presence of a stable saturated zone during periods of excess rainfall. This temporary mass of water forms above a horizon considered impermeable or slightly permeable, located around 60-70 cm at the Jaillièrre.

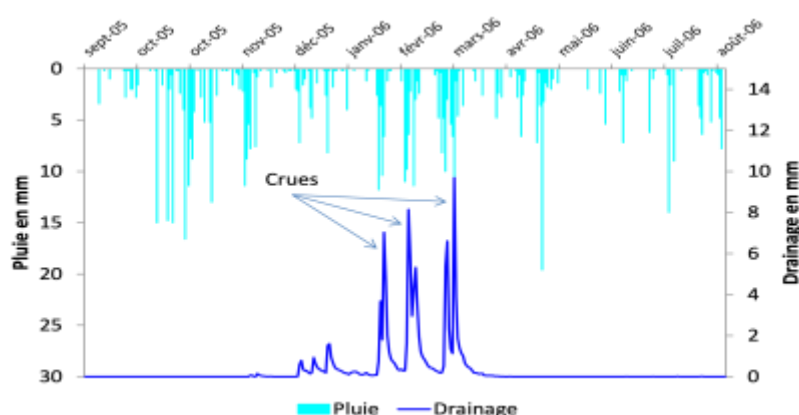


Figure 3: Daily drainage - plot 3 - 2005-2006

The operation of drainage networks is conditioned by the presence of excess water. During periods of excess rainfall, the drainage network inflow is often continuous and concentrated into a winter hydrological season in temperate climates.

At the Jaillièrre, the winter hydrological season, also called drainage season, is generally observed between December and March: on average from November 28 to March 19, about 3.5 months of drainage. Interannual variability is significant and directly correlated with the rainfall of each campaign. It lasts from a few days – 5 days in 2004-2005 – to several months – 205 days in 2000-2001, or almost 7 months.

Most of the outgoing water flows by drainage or runoff are observed during the hydrological season. Secondary flows, during the off-season winter drainage period, are observed on average every other year at La Jaillièrre, during intense rainfall events (volume, duration), most often in spring between April and June (Figure 4).

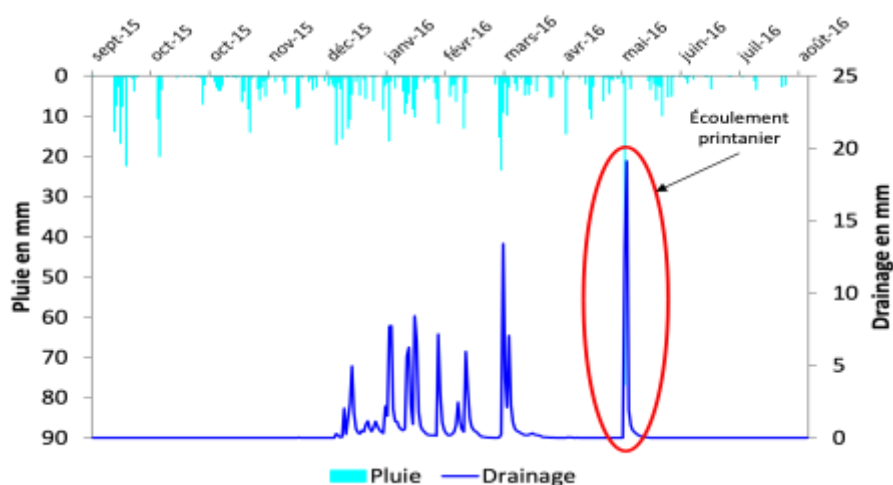


Figure 4: Campaign with spring flows - plot 4 - 2015-2016

Although secondary, these episodes contribute to the annual drainage budget: for years with runoff outside the winter hydrological season, this represents on average 11% of the total drained water residual, between 0.6% and 41% depending on the year.

During a measurement campaign, the accumulation of daily water flows shows a "stair step" profile (Figure 5), illustrating the succession of draining episodes and lull episodes: the most significant floods are represented by sudden and significant increases in the cumulative curve. During the period of excess rainfall, the drainage season operates continuously, with the frequency of return rains limiting the complete drying up of flows.

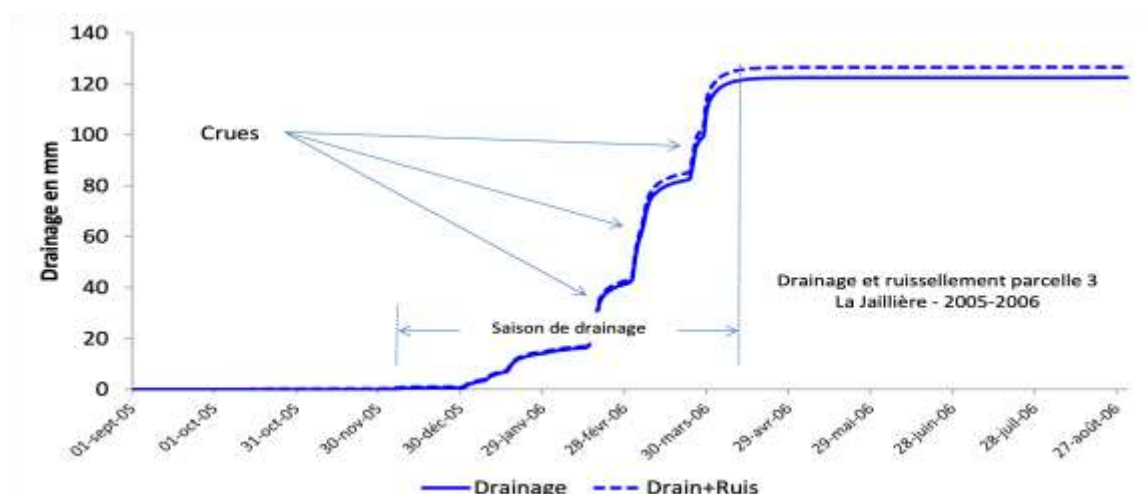


Figure 5: Cumulative drainage and runoff during the 2005-2006 season (plot 3)

Spring flows, unlike the winter hydrological season, are not predictable: they result from sudden and isolated rainfall events, such as thunderstorms. The drainage network inflow is then the result of rains whose intensity and/or volume cause rapid and sometimes significant water transfers (Figure 6), regardless of the soil's ability to store this water.

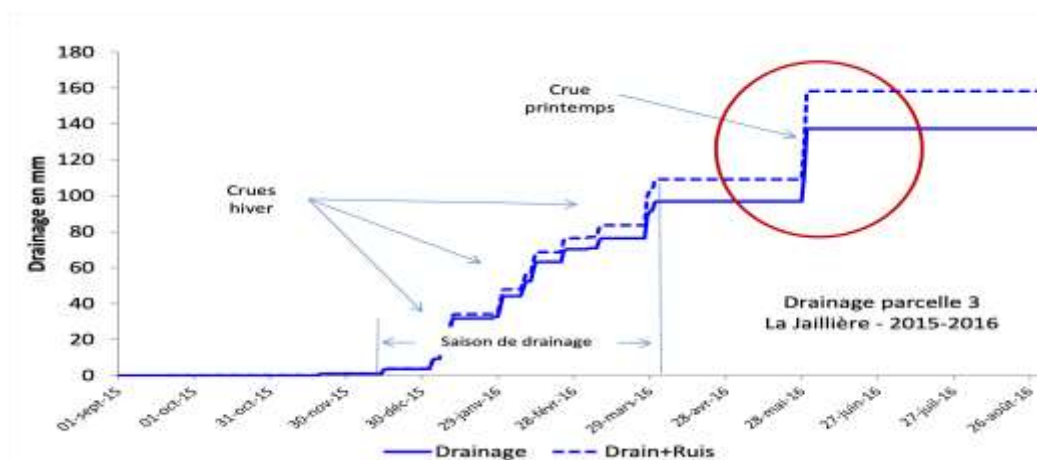


Figure 6: Accumulation of drainage and runoff during the 2015-2016 season (plot 3), with spring discharge

The measurement campaigns are successive and do not resemble each other, notably due to the variability of annual rainfall. The sheets of water drained or dripped vary a lot from one measurement campaign to another (Figure 7), and are very dependent on cumulative rainfall recorded from the end of summer until the end of winter.

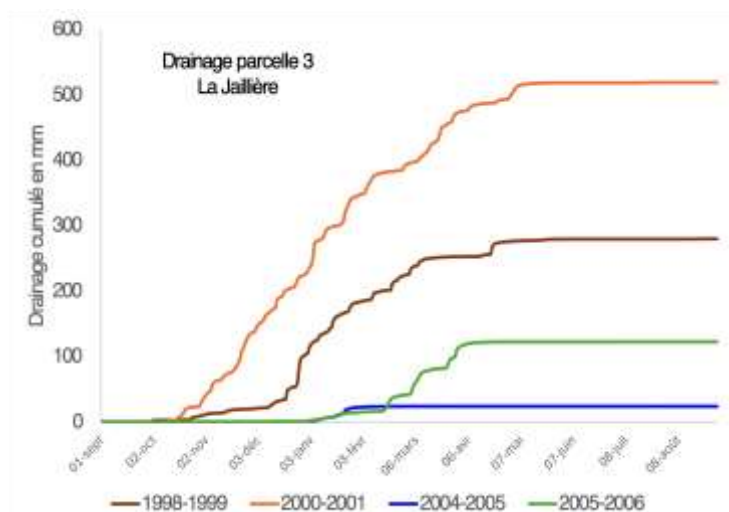


Figure 7: Variability of cumulative drainage for four measurement campaigns

CHARACTERIZATION OF THE WINTER HYDROLOGICAL SEASON

Despite the interannual variability of rainfall and cumulative drainage and runoff depths, the network water supply episodes are generally grouped into a main winter season: each year, the plots of the Jaillièr experimental system drain at the same time. (Figure 8). However, differences in behavior exist depending on the topographic position on the slope (Arlot, 1999), notably for peak flows and the duration of drying-off, as well as for the accumulation of the annual water layer.

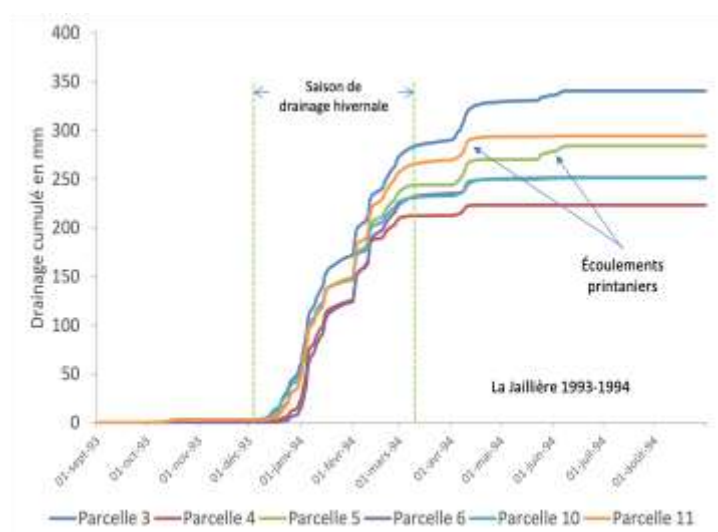


Figure 8: Seasonality of flows and comparison of cumulative drainage between plots during a measurement campaign (1993-1994)

The construction of the double-cumulation curve [Pluie-Lame d'eau] (Lesaffre, 1988) represents the evolution during the measurement campaign of the drained (or streamed) accumulation as a function of

the rainfall accumulation. This form of data representation makes it possible to identify with a reasonable degree of certainty the three phases of the hydrological season, and to determine their bounds (dates at the beginning and end of each period) (Figure 9).

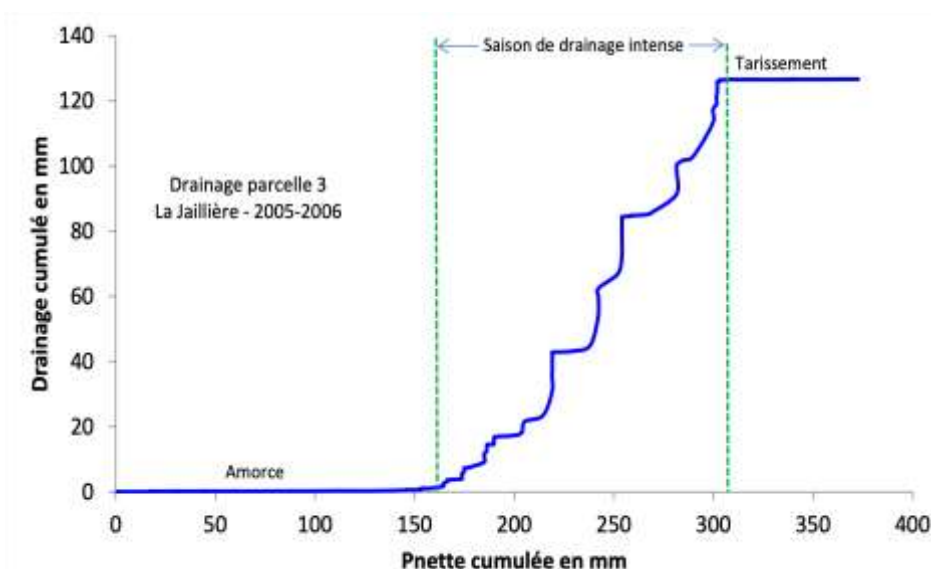


Figure 9 : Double-cumulation curve rain – water strip

The hydrological season begins first with the recharge of soil water by the rains of late summer and autumn. When this reservoir reaches its maximum storage capacity, any new water supply is an excess that the soil cannot store: this is the initial phase of drainage, with the first flows into the networks. This phase is little marked at the Jaillièrè, and represents only a few millimeters of drainage.

The intense drainage season (IDS) is the main component of the hydrological season. Although punctuated by the rainfall regime, rain and calmness occur throughout the period, the perched water table is installed and supplies water to the drainage and runoff networks. During the SDI, flows are practically continuous and the return of rain to the networks (drainage and runoff) is, on a trend, close to net recharge⁵.

Finally, with the increase in climate demand (ETP), the supply of water to the networks decreases rapidly: the drying-up phase is sudden and rapid. The resumption of flows is still possible with significant rainfall episodes, but then occurs outside the winter hydrological season.

MODELING OF THE INTENSE DRAINAGE SEASON (IDS)

The double-accumulation curve covers the entire crop year, from 1 September to 31 August. Its overall shape reveals the three distinct segments – initiation, season of intense drainage and drying up – with, at each change of slope, a clear inflection between two successive segments.

The identification of the intense drainage season (IDS) is graphically feasible, by expert judgment, from the inflections materialized on the double-accumulation curve by points [A] and [B] (Figure 10). The start and end dates of the SDI are then found in the data table used to construct the chart.

⁵ Net recharge : positive part of the climate balance sheet [P-Etp], with P for rain and Etp for potential evapotranspiration. At the scale of the agricultural year (1 September-31 August), net rain (Pnette) is a positive cumulative effect directly related to the rainfall of the year, lower than the cumulative effect of gross rain.

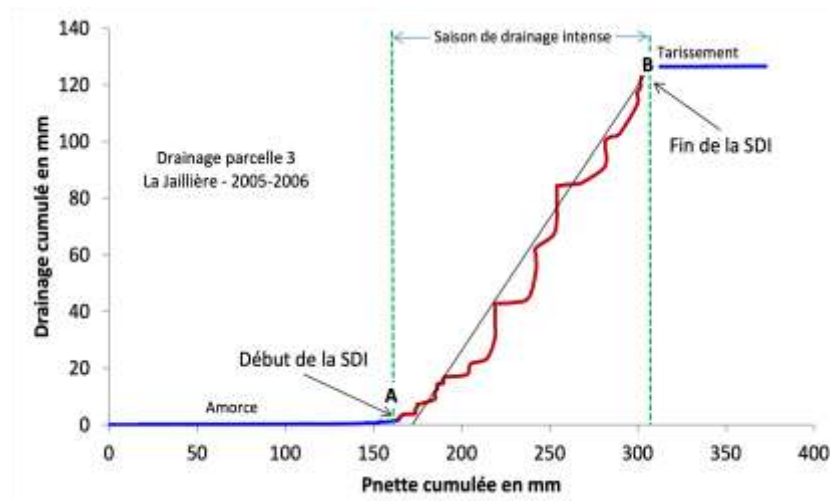


Figure 10 : Identification of the IDS on the double-accumulation curve

This representation of a three-segment curve is reproducible for all the plots of the experimental setup and for all the study campaigns. Only the abscissa and ordinate values change, in connection with the annual rainfall and the hydrological response of each plot.

The water balance in a drained plot is discussed by various authors (Zimmer, 1988 – Arlot, 1999) and can be written as follows :

$$BH = (P + Ir - Etr) - (D + R + IP) \Delta s$$

With (expressed in mm) : BH : water balance
P : rain
Ir : irrigation
Etr : real evapotranspiration
D : drainage
R : runoff
Ip : deep infiltrations
 Δs : change in soil water stock

A simplified version of this balance residual is proposed for calculation during the intense drainage season, with actual evapotranspiration (Etr) taken equal to potential evapotranspiration (Etp), a variation in soil water stock (Δs) considered negligible, and the lack of irrigation in winter in the context of the study. The balance residual is then written:

$$BH = (P - Etp) - (D + R), \text{ expressed in mm}$$

Arlot (1999) introduces the concept of restitution differential (DR) to designate the unmeasured terms of the water balance of the drained plot during the intense drainage season, and represented by the following equation:

$$DR = (D + R) - (P - Etp), \text{ expressed in mm}$$

With: D=drainage, R=runoff, P=rain, Etp=potential evapotranspiration

She deduces the discharge coefficient (CR) by the drainage network, also calculated during the IDS:
 $CR_{IDS} = D / (P_{nette})$

This discharge coefficient represents the share of net rain discharged by the drainage network. It can also be calculated for runoff by replacing the term [D] with the term [R] in the equation. To simplify and automate the processing of intense drainage season data, a statistical method is proposed (Dutertre & Duyme, 2017, personal work) : annual double-cumulations [Pnette-Lame d'eau] are represented by a model using segmented linear regression. (Muggeo, 2003). The global linear model is composed of linear submodels with continuity constraints to preserve the dependence of the three segments on each other for the entire measurement campaign.

The model calculates the inflection points of the cumulative curve and represents them graphically with dashed lines (Figure 11). The season of intense drainage is the intermediate segment. The determination of the two inflection points makes it possible to calculate the IDS parameters: start and end dates, duration in days, drained volume, discharge coefficient⁶.

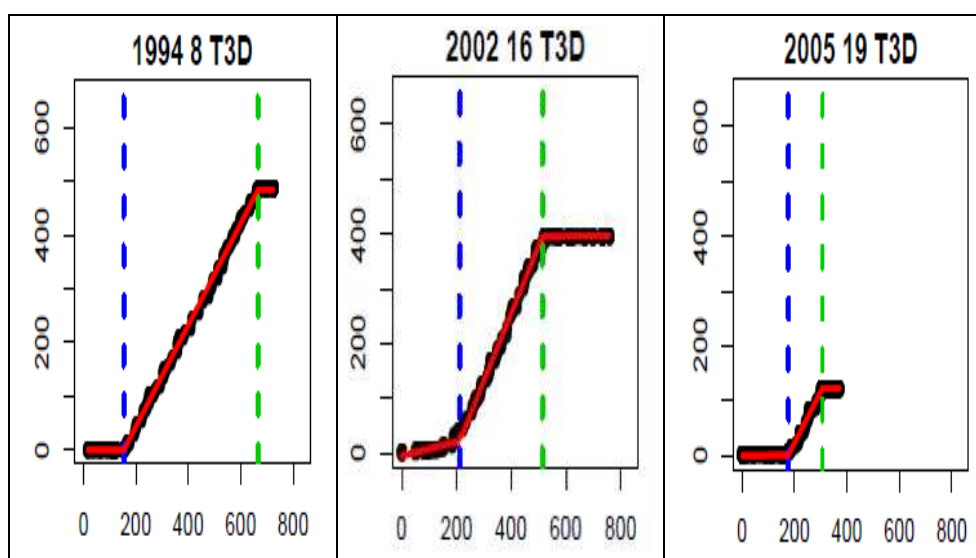


Figure 11: IDS defined by segmented linear regression – Plot 3 – With measurement campaigns from left to right 1994-1995, 2002-2003 and 2005-2006 (Dutertre & Duyme, 2017)

This way of processing data offers some advantages:

- The use of a standardized and homogeneous method for processing all data (all campaigns, all plots), which makes it possible to avoid the approximations of "expert testimony".
- Processing of a long-term database.
- Optimized processing using scripts under R.

*Reminder: plot T1 (T1R in the table) is not drained, and plot T5 is not equipped with a runoff trap. Data from the 2004-2005 crop year (near zero drainage) were removed from the analysis.

For experimental devices with daily data of drainage and/or runoff water depth, the analysis method is easily transposable.

The season of intense drainage is very variable from one year to another, in connection with local rainfall, which makes it difficult to draw general conclusions from annual data. In the Jailli re experiment, the

⁶ Discharge coefficient: fraction of the net rainfall balance discharged by drainage (or runoff). The net rain balance [P-Etp] is calculated during the IDS, taking into account that at this period of the measurement campaign (winter), Etp and Etr (actual evapotranspiration) are closed

work did not reveal an effect of agricultural practices on the return of rainwater to the drainage network. However, the data acquired on solute transfers by drainage and runoff could be consolidated by a better knowledge of the hydrological behaviors of the study environment.

Table 3 : Examples of discharge coefficient for drainage and runoff for the period 1992-1993 to 2011-2012

Campagne	Drainage						Ruis.ND	Ruissellement parcelle drainée				
	T3D	T4D	T5D	T6D	T10D	T11D	T1R	T3R	T4R	T6R	T10R	T11R
1992-1993	0.57	0.59	0.65	0.65	0.75	0.90	0.71	0.15		0.09	0.04	0.06
1993-1994	0.99	0.84	0.86	1.00	0.78	0.98	0.80	0.10	0.32	0.07	0.02	0.03
1994-1995	0.95	0.94	0.98	1.02	0.83	1.21	0.82	0.19		0.12	0.12	0.08
1995-1996	0.82	0.78	0.78	0.77	0.68	0.89	0.65	0.07	0.11	0.06	0.05	0.04
1996-1997	0.93	1.05	0.85	1.04	0.95	1.09	1.23	0.11	0.12	0.07	0.11	0.03
1997-1998	0.79	0.86	0.75	1.12	0.63	0.83	0.59	0.06	0.14	0.06	0.17	0.07
1998-1999	0.89	0.88	0.68	1.10	1.06	0.87	0.96	0.10	0.23	0.09	0.23	0.05
1999-2000	0.75	0.76	0.62	0.95	0.74	1.00	0.70	0.09	0.15	0.18	0.24	0.03
2000-2001	0.99	0.90	0.71	1.12	0.88	1.06	0.90	0.23	0.32	0.21	0.16	0.21
2001-2002	0.78	0.83	0.52	0.99	0.83	0.92	0.89	0.19	0.09	0.13	0.07	0.07
2002-2003	1.22	1.06	0.61	1.34	0.94	1.23	1.12	0.20	0.16	0.08	0.17	0.08
2003-2004	0.82	0.91	0.61	1.02	0.67	1.12	0.77	0.16	0.17	0.09	0.21	0.05
2005-2006	0.93	0.87	0.46	0.86	0.58	0.92	0.99	0.03	0.05	0.03	0.07	0.02
2006-2007	0.91	0.83	0.53	1.29	0.62	0.67	0.57	0.15	0.02	0.06	0.35	0.50
2007-2008	0.66	0.82	0.43	1.09	0.65	0.83	0.61	0.38	0.03	0.15	0.10	0.17
2008-2009	0.83	1.08	1.29	1.20	0.90	1.13	0.70	0.06	0.03	0.05	0.07	0.04
2009-2010	0.77	0.91	0.50	1.13	0.72	0.96	1.03	0.03	0.04	0.07	0.08	0.03
2010-2011	0.43	0.85	0.67	1.04	0.70	0.92	0.62	0.03	0.03	0.04	0.11	0.04
2011-2012	0.12	0.40	0.69	0.89	0.13	0.18	0.27	0.01	0.01	0.01	0.05	0.00
Moyenne	0.80	0.85	0.69	1.03	0.74	0.93	0.79	0.12	0.12	0.09	0.13	0.08
Médiane	0.82	0.86	0.67	1.04	0.74	0.92	0.77	0.10	0.11	0.07	0.11	0.05
Ecart-type	0.16	0.1	0.14	0.12	0.13	0.15	0.18	0.07	0.08	0.04	0.07	0.07
Moyenne	0.84						0.79	0.11				
Médiane	0.86						0.77	0.08				
Ecart-type	0.17						0.18	0.07				

AGROMETEOROLOGICAL MODELING

ARVALIS has been developing and using the agrometeorological model CHN for years to represent the soil-plant-climate system, and thus simulate the growth of cultivated plants in the different French pedoclimatic contexts.

More specifically, this model integrates a water balance calculation module that allows the management of water flows in interactions between the climate (water inflow, evaporation), the soil (reservoir) and plants (water consumption). For each simulated system, the water inputs are meteorological inputs (especially rainfall), irrigation inputs and the state of the available stock in the soil at time T. Meteorological data are provided by the stations closest to the study site.

The soil characteristics come from an internal ARVALIS database. This database lists a large part of the French soils dedicated to field crops. The different soil horizons are precisely described, in particular the texture of these horizons (clay, silt, sand).

Without going into the details of how the model works, several components of the water balance are managed by known algorithms and widely used by the scientific community. The calculations are daily and carried out by cutting the soil into equal slices of 1 centimeter, from the surface to a depth of 1 meter.

The percolation of water is simulated centimeter after centimeter, from the surface of the soil to the deepest sections of soil. When the percolated water reaches the level of the drain, a share of this flow is drained: the percolating volume is obtained by difference.

The runoff observed in the hydromorphic soils of the Jaillière is mainly a runoff by saturation. The model evaluates the progressive saturation of the first 30 centimeters of the ground, from the deepest slice up to the surface. When water saturates the first centimeter of soil, infiltration and percolation are no longer possible and runoff becomes the way to evacuate the water. The estimate of the runoff volume is also obtained by difference.

For these two particular cases of drainage and runoff, the data measured in the Jaillière system largely contributed to the calibration and validation of the simulated data ().

MULTI-YEAR EVOLUTION OF DRAINAGE

The existence of an experimental device several decades old allows to take a different and singular look at the acquired data, especially when the measurement protocol has not changed during all these years. If the measurements of the Jaillière trial are carried out at hourly time steps, the data are processed and compiled on a daily, annual, and multi-year scale.

The multi-year water residuals are accumulated from 1 September 1992, after the installation of the last experimental plots of the device, plots 10 and 11. The grouping and comparison work concerns plots T3, T4, T5, T6, T10 and T11 of the trial, because they are located on the same site.

The accumulation of water residuals drained during thirty-eight years of measurement (Figure 12) varies practically from simple to double: 4922 mm for plot 5 and 9245 mm for plot 6. These plots are however located on the same site, and contiguous on the same slope. The drainage accumulations of the other plots are intermediate at these two extremes.

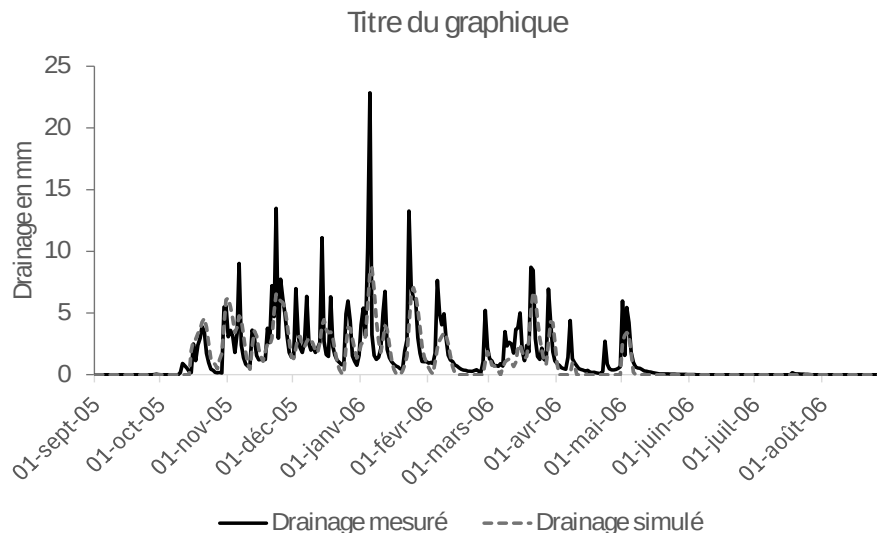


Figure 12 : Comparison measured-simulated drainage

Over time, the return to drainage has several distinct periods:

- During the first period, the curves show a similar evolution, and the gaps between them are not very large: the drainage curves are globally homogeneous.
- A change in behaviour occurred between 2001 and 2003, depending on the plot : the curves gradually became different from each other, with deviations widening from year to year.

- A third period begins between 2010 and 2013, with drainage rising or falling again depending on the plots, with gaps widening between extreme situations.
- Finally, a fourth period seems to have emerged since 2018/2020, with a rather marked change in the drainage of plots 3 (lower restitution) and 4 (increased).

The reasons behind these changes are difficult to identify: is it related to a change in local rainfall, the quality of drainage networks, or the effects of agricultural practices?

To date, and given the knowledge acquired, it is impossible to identify an effect of one or more agricultural practices (tillage, crop rotation, ...).

Regarding the meteorological data, an evolution is observed over time, with changes by sequence: a first inflection of cumulative rainfall (raw rain) and net rain (P-ETP) around 2004, then a second around 2012 (Figure 13).

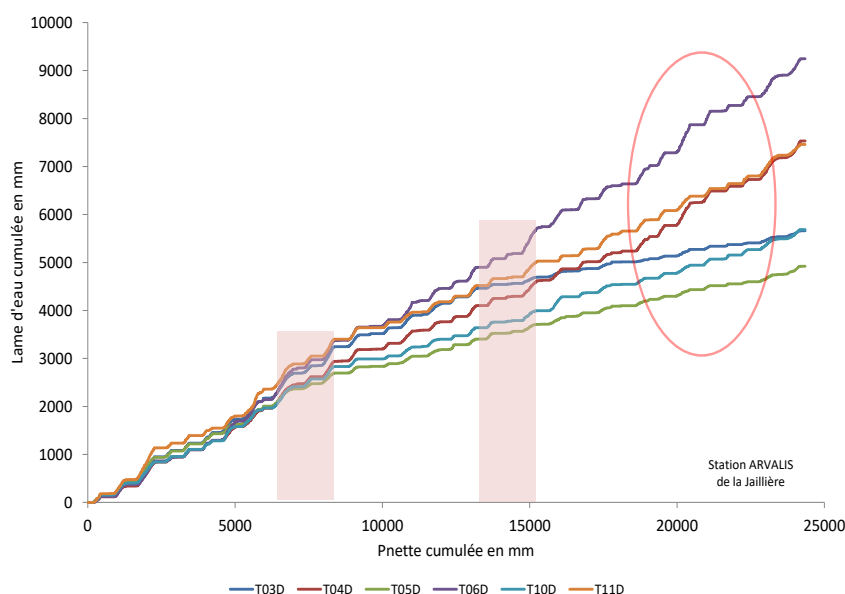


Figure 13. Double-accumulation Pnette-drainage from 1992 to 2025

The average annual rainfall varies over the three identified periods:

Measurement Campaign	Average annual rainfall in mm
1992-1993 to 2003-2004	782
2003-2004 to 2011-2012	627
2011-2012 to 2024-2025	749

However, it is difficult to state with certainty that this change in local rainfall is the sole cause of the evolution of the drainage of the Jaillière plots.

The layout of the test plots in the field leads to propose a hypothesis of operation according to the direction of the main flow (Figure 14). The 6 plots studied are arranged by pairs of plots on 3 hydrological slopes determined by the direction of the greatest slope.

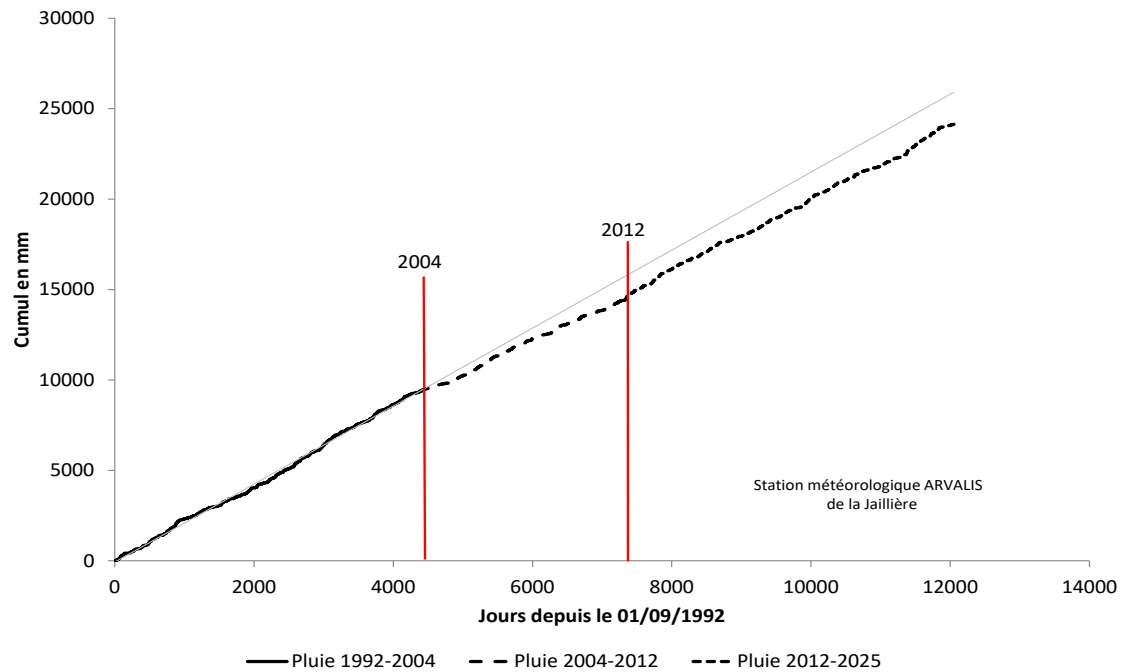


Figure 14 : Multi-year change in cumulative rainfall

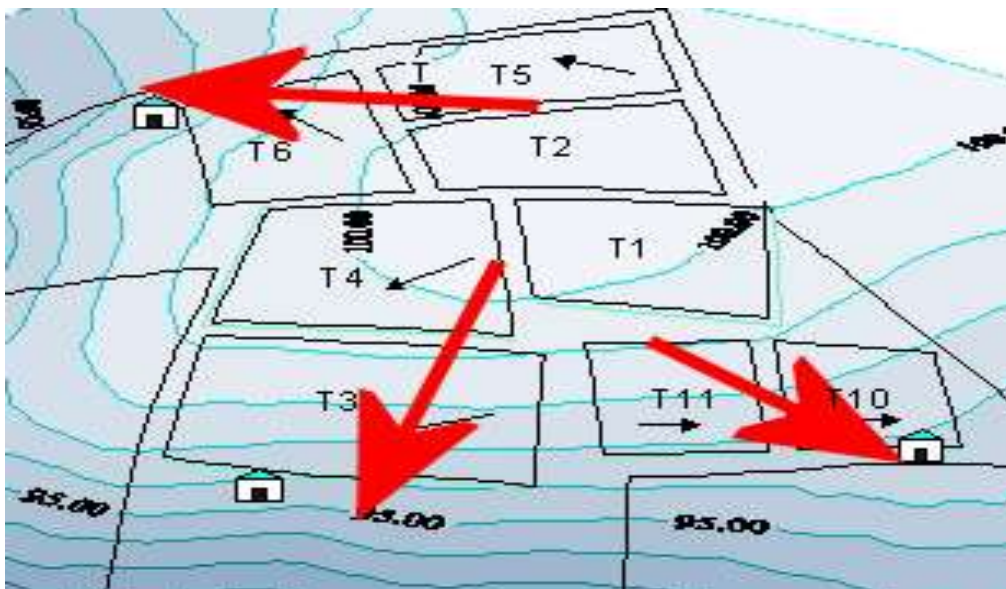


Figure 15 : Experimental device of la Jaillière : water circulation

This organizational scheme leads to propose a new reading of the cumulative drainage curves by calculating the average water depth of each pair of plots: [T3, T4], [T5, T6] and [T10, T11].

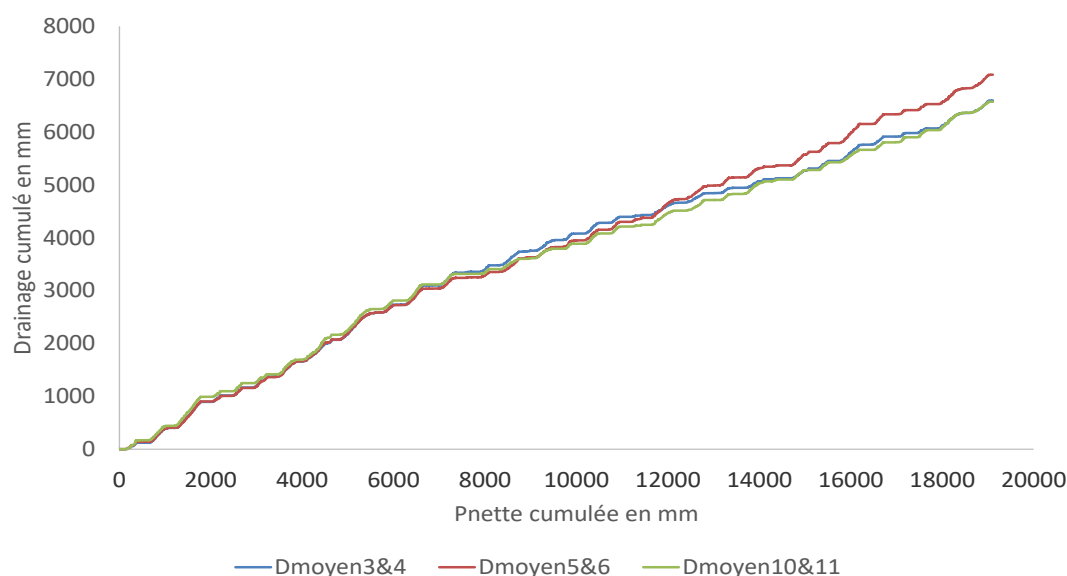


Figure 16 : Mean drainage curves

Arlot (1999) refers to the presence of a confined aquifer at shallow depth, which is described as a permanent water table in contrast to perched winter water tables. This aquifer is supposed to influence the drainage regime of the test plots on the slope. The installation of deep piezometers confirmed this hypothesis, without specifying the origin of the water feeding the permanent groundwater.

Hydraulic interactions between surface and depth are therefore possible in the context of the Jaillièrè. The idea of a "medium operation" of the site, where the test plots are located, is acceptable. Each plot gives an individual hydraulic response marked by its interactions with the other plots in proximity and with the natural environment, composed of cracked shale.

CONCLUSION

Long-term experiments are infrequent: with the experimental device of the Jaillièrè, having a database of nearly forty years on agricultural drainage is in itself a real asset. The contribution of knowledge on the hydraulics and hydrology of the drained plot, both for drainage and runoff, has made it possible to understand and partly explain the transfer processes of solutes (nitrate, phosphorus, plant protection products).

The importance of Jaillièrè data is now recognized, both internally at ARVALIS and with its partners in agronomic research, including INRAE, particularly for modeling work. However, data analysis, especially at the multi-year scale, can be pursued by further investigating interactions between the test plots and the natural environment, to better understand water pathways, and improve knowledge about water resources.

Finally, a more in-depth analysis of local climatology (rain, evapotranspiration) should help to assess the consequences of climate change on the evolution of water resources, a subject already very present today in many research projects. And the Jaillièrè system seems suitable for addressing certain issues.

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