CONFERENCE

IRRIGATION

QUELLES STRATÉGIES POUR ÉCONOMISER L'EAU ?
WHAT STRATEGIES FOR WATER SAVINGS ?

REGARDS CROISÉS EUROPÉENS

SHARING EUROPEAN VIEWS

13 - 14

nov. 2019

MONTPELLIER

FRANCE

irstea LA SCIENCE AU CŒUR DE L'ENVIRONNEMENT

L'Europe s'engage en Occitanie

UNION EUROPÉENNE

La Région Occitanie Pyrénées - Méditerranée

PROJET COFINANCÉ PAR LE FONDS EUROPÉEN AGRICOLE POUR LE DÉVELOPPEMENT RURAL
L'EUROPE INVESTIT DANS LES ZONES RURALES

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

Réseau Rural Français 2014 - 2020

MUSE MONTPELLIER UNIVERSITY OF EXCELLENCE

KEY INITIATIVE WATERS

INVESTISSEMENTS D'AVENIR

G-eau Gestion de l'Eau, Acteurs, Usages

Montpellier SupAgro

AFEID Association Française pour l'Eau, l'Irrigation et le Drainage

AIRMF Association des Irrigants des Régions Méditerranéennes Françaises

aGRICULTURES & TERRITOIRES CHAMBRE D'AGRICULTURE OCCITANIE

aGRICULTURES & TERRITOIRES CHAMBRE D'AGRICULTURE PROVENCE-ALPES-CÔTE D'AZUR

AQUA VALLEY

IRRIGATION IN BULGARIA FOCUSING ON WATER SAVINGS ATTEMPTS AND ACHIEVEMENTS*

*Prof. Zornitsa Popova, PhD and DSc

“N.Poushkarov” Institute of Soil Science Agrotechnology and Plant Protection. Department of Physics, Erosion, Soil Biota

Irrigation in Bulgaria focusing on water savings attempts and achievements

Considering the present enlarged population on the earth and the on-going processes of climate change and uncertainties, the importance of irrigation is supposed to increase substantially, while available water for irrigation is expected to get scarce (Alexandrov(Ed.)2011; Slavov et al, 2013; Moteva et al,2015; Popova&Pereira, 2008; Popova, 2010; Popova et al, 2011;2014; 2015). Surface irrigation has been a dominated practice worldwide, even when the remaining technologies, as sprinkler and drip irrigation, have a significant role for our society (Varlev, Popova, Gospodinov, 1998; Popova, Mailhall et al.2005).

The objective of present report is:

to share a feedback on quantitative water savings/environment protection achieved in Bulgaria, using results of experimental trials and validated simulation tools application at point & field scale.

The performance control is related to improved furrow irrigation technologies by monitoring water application uniformity and efficiency under Traditional Continuous and Surge Flows as well as other water saving practices.

1. Importance of irrigation and soil TAW for crop productivity

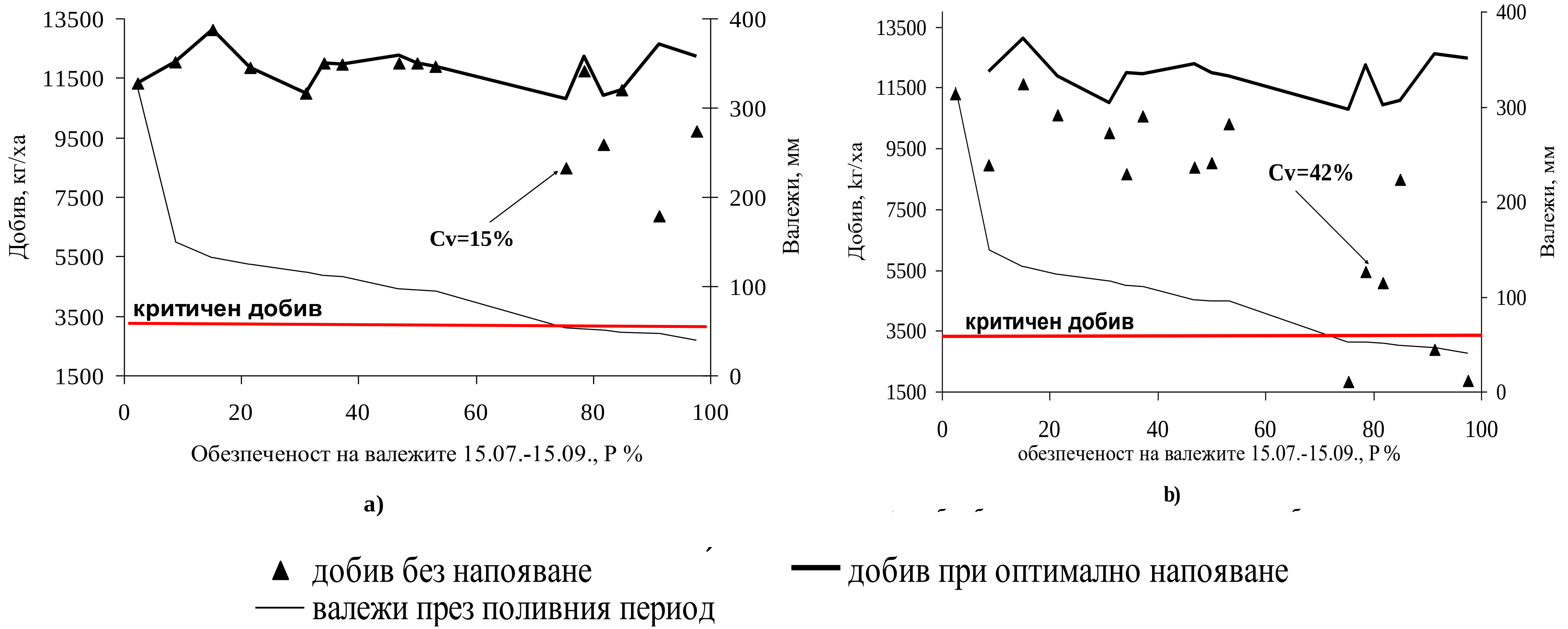


Fig. 1 Yields of **irrigated** (upper full line) and **rainfed maize (▲,** Kn509 variety**)** in relation to the probability of precipitation 15/07-15/09 at: a) **vertisol** (**TAW**=180 mm/m), Bojurishte; b)**chromic cambisol** (**TAW**=106 mm/m)**,** Chelopechene,Sofia field,**1960-1990.**

•Considering the soils of contrastive **TAW** (**180** versus **106 mm/m**) under the **Moderately-continental** climate (Sofia field), irrigation application leads to **1.5** versus **3.4** larger crop productivity comparing to the rainfed maize yield in the dry years of **P** > **75%**. An important fact is also that irrigation mitigates yield variability over the whole range of different climatic years when maize is grown on a soil of small **TAW** (**106 mm/m**) that is a prerequisite for a stable economical development without risk in Sofia field (Fig.1b).

2.a) Actual state of irrigation in Bulgaria

A report at World Water Day, 2019 by Eng. Valentin Slavov

- "Irrigation Systems" **IS** is a Single Trading Community **STC**. Its main activities are to supply water for irrigation and to perform exploitation and maintenance of technical irrigation equipment. At the present, number of dams in Bulgaria is **6862**. Last reports have shown that, considering the constructed **7 million decare**, only an area of less than **3 to 3.5 million dka** is **"fit" for irrigation**. Thus, **8 - 9 %** of the potentially fit irrigation area **is irrigated now** that is incomparable to the situation in the past. During the last 30 years **800 Pumping Stations** (**PS**) have been demolished, while **80** remained for **irrigation**. A "free" irrigation event was delivered only in 2000 and 2007. Since 1997 the price of **water for irrigation** augmented **1.5 folds**.
- Presently, about **300-320 thousand dka** are under irrigation. Nevertheless that pumping water is expensive, the only possibility is to make use of ground water for irrigation . **The main problems for irrigation in Bulgaria are: 1) the lack of up to date equipment, 2) the expensive electrical energy and 3) the expensive water.**
- **The Danube**, the most exploited source for maize irrigation in the past, is not used for that any more. The reason is that it is flowing in the lowlands (at about **30m altitude**), while the land fit for irrigation is located at a higher altitude (**60 to 200m**). Thus, water needs to be pumped first to a **50 m altitude**, than to **100, 250 and 300m** respectively for **2nd, 3rd** and **4th step** that is not profitable for the farmers. The only irrigation community **"the Danube"**used to irrigate last in **2004**, while the only functioning pumping station is in **Shabla**, North-East Bulgaria. The new founded **"Beli Lom"** irrigation community, in order to be profitable regardless of the expensive water of **0.45-0.48 lv m^{-3}**, has changed the previously cultivated crop **to strawberries & raspberries**. The average price of water, computed as acceptable for the farmers is **0.25 lv per m ^{3}**.

2.b)State of Irrigation and measures to overcome the crises

A lot of objects, functioning within the framework of *"Irrigation Systems"* (**IS**), used to be visited by Prof. Ivan Varlev during the summer of 2011 (Popova (Ed), 2012). That was a real opportunity to get a professional evaluation of the present irrigation systems in Bulgaria that is generally different than that of 20-25 years ago.

a. "Pazardjik" is one of the oldest **IS** in Bulgaria. The functioning channels, constructed in the XVII and XVIII century, are still in use today. The transportation of water is performed by gravity and its price (**0.13 lv/m^3**) is acceptable for water users, including for maize irrigation. Several vegetable fields under "short furrows" irrigation, receiving water through cutting the ditches of the temporary channel by using a hoe, have been attended (**Fig.1**).

Fig.1 Vegetables' irrigation in short furrows by using a hoe. *"Pazardjic" Irrigation System*

Fig.2a. Use of flexible distribution pipeline **Φ200**, attached to a movable riser **Φ150 mm** for delivering water to a furrow set (**15-30dka**), ***ASSI*** , Chernogorovo.

Total irrigated area was **51 000 dka**, **49 000** under traditional surface irrigation, **500** – under sprinkler and **1 000** –under drip irrigation. Considering the total constructed irrigation area of **540 000 dka**, **235 000**, or **43%**, are **"fit"** for irrigation. Thus, the percent of irrigated area relative to the area **"fit"** for irrigation is **22%** (one of the highest under present irrigation conditions). The questions "what part of "unfit" area could be rentable to irrigate in the future" and what "investments should be required for that", are not discussed. Topographic and soil condition relative to the region of Pazatdjik are mostly appropriate for contemporary irrigation in furrows of **200 – 500 m** length. Irrigation water is usually delivered by plastic pipelines (**Fig.2a**).

2c) Technology of furrow irrigation uniformity improvement -irrigation with variable stream during stage II:

Automated System for Surface Irrigation ***ASSI***
Prof.Iv.Varlev (1969-1990)

The movable risers (**Fig.2b**) receive directly water from the *Automated System for Surface Irrigation* (Varlev,1977,**USPatent**;Varlev&Popova, 1987).A relation ship between soil test results (clay content & Atterberg's flow limit) and *average labour requirements* P_{av} **(man min/riser)** relative to 39 pipelines of the ***ASSI*** was established (Popova 1988a &1988b). Each distribution pipeline delivers water to **13 – 30 dka** (**Fig.2b**), while the movable risers are pushed under plough layer after irrigation season.

Fig.2b ***"Cut Back"/"Variable stream" irrigation during irrigation stage II:*** movable plastic risers **Φ50** set into operational position by the water pressure head in the **underground distribution pipeline** of ***ASSI*** (Varlev, 1971; 2011;Varlev &Kolev,1973).

Fig.2c Underground distribution pipeline with **a large movable riser Φ150** for simultaneous delivery of **30-35 l sec^{-1}** to **30-40 furrows**. Such a riser delivers water consequently to the left & right and covers a **100m strip** of land, or **20 to 40 dka** irrigated area. Flexible distribution pipeline diameter could be Φ200.

3. Nonuniformity of application depth distribution

A. Stages of water flow under furrow irrigation

- In order to establish application depth distribution along the furrow length and over the total irrigated area it is required to be familiar with the stages to put irrigation is into practice.
- **Stage I** of water advance and intake into the soil starts at the beginning of irrigation event and continues till the stream forehead reaches the furrow tail at **l**<L (**Fig.3a, the full line**). **During that stage opportunity time of water intake is different over the furrow length.**
- **Stage II** is accomplished **when a continuous layer of water is obtained over the whole furrow length** (**Fig.3a,** line in dashes) that is achieved by two different irrigation techniques: **a)** by irrigation runoff or **b)** by delivery of variable irrigation streams. **During that stage opportunity time for water intake in the soil is constant over the whole furrow length.**
- **Stage III** begins in **water "cut-off" time** at the furrows' head (**Fig.3 b**). **The water runoff starts** during that stage that produces a formation of the so called **"Back end".** Nevertheless**, intake of water in the soil is still going on that , due to the large number of surges, is of great importance for the water saving effect of surge irrigation** (Varlev, 2011).

a) Stages I and II

b) Stage III

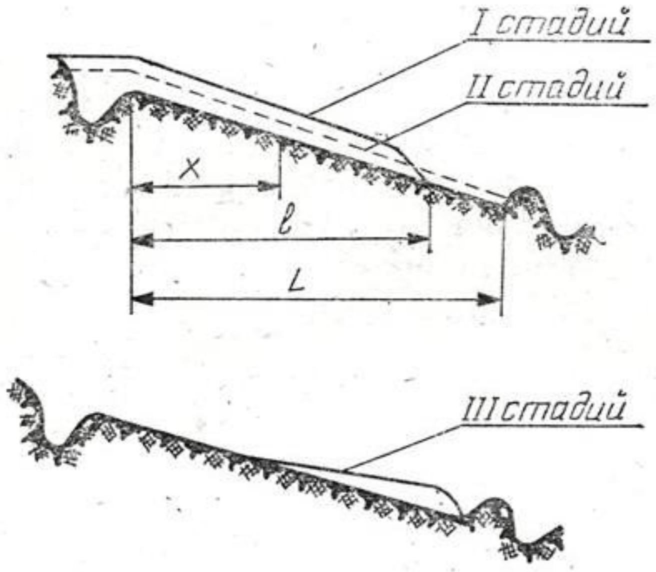


Fig.3(25) Stages of stream advance under furrow irrigation

The disadvantages of **traditional furrow irrigation** are related to required uniformity of water distribution along and across the field. Thus, **second stage duration** (Fig.3a) should surpass that of the first one by over **20-30%.** In that case significant run-off and deep percolation water losses are inevitable.

3a. Technologies of furrow irrigation uniformity improvement during Stage I:

4.1. After initial water application (a "surge" of a 30 min **"on-time"**) and during the following **"off-time"** (next 30 min), due to the gravity and capillary forces some movement of available soil water is taking place in the "wet" part of the furrows (**Fig.4**; Varlev, 2011).

During that movement irrigation water usually transports fine soil particles that fills in the pores of soil. As a result, water intake rate decreases gradually during **next surges** (**Fig. 5b, Stage I**), if compared with that observed under **traditional** (continuous) furrow irrigation (**Fig.5a, Stage I**). The reduced soil permeability leads to **a faster stream advance** to the furrows' tail and **a smaller depth intake under surge** irrigation (**m_2<m_1**). That is predominantly the case in the **upper 1/2 - 3/4** of the furrow length, where water used to flow for a much longer time (**Fig.5b, Stage I**). Thus, **a better water distribution uniformity could be even achieved during Stage I** of the furrow irrigation process.

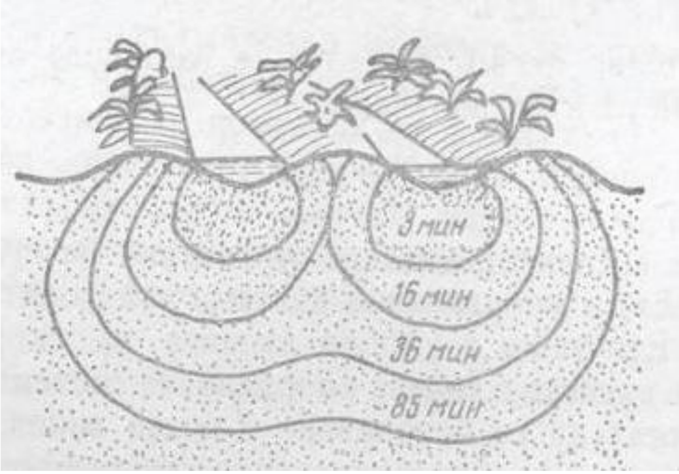
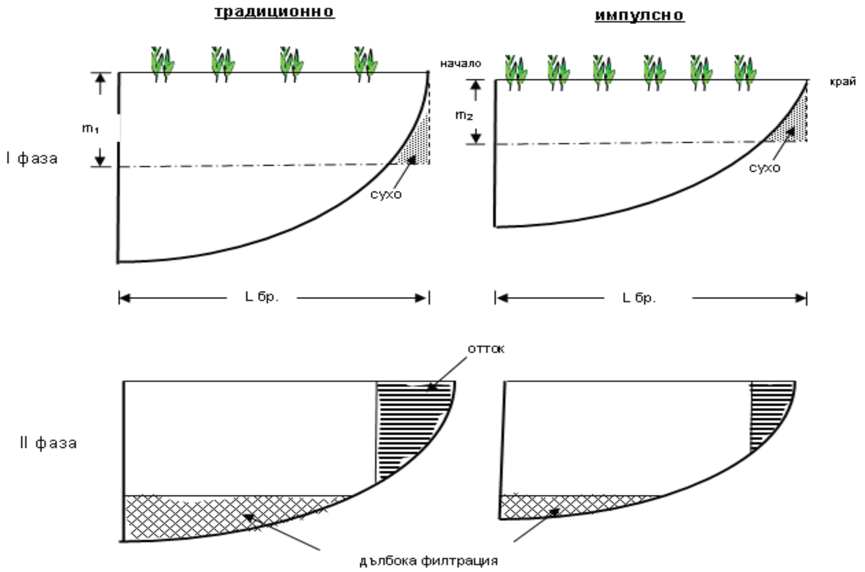


Fig.4 (3) Down wards and Side wards soil water (humidity) movement in the wet part of the furrows under "surge" irrigation.

a) Traditional Irrigation | **b) Surge Irrigation**

Stage I

Stage II



Deep percolation | **Runoff**

Fig.5. Runoff and Deep percolation losses relative to Stage I and Stage II under: a) Traditional (left) and b) Water saving Surge (right) furrow irrigation (Varlev, 2011).

3b. Technologies of furrow irrigation uniformity improvement during Stage II

- **During Stage II** (line in dashes, **Fig.3a**) surge furrow irrigation shows also substantial advantages. Regardless of the fact that streams flow constantly at the furrows' heads, runoff is substantially smaller at the furrows' tail (**Fig.5b**). It is due to restricted water delivery at the furrows' head during surge "off-time", while the main part of runoff water is taken in by the soil. So, during **Stage II**, runoff losses are substantially smaller if compared with those associated with traditional furrow irrigation (**Figs. 5a 5b**).
- Decrease of water intake rate in the soil and runoff at the furrows' tail under surge irrigation lead to a reduction of application depth and **water saving up to 20-30 %** of submitted water (**Figs. 5a 5b, Stage II**). As a result, a high uniformity level of soil moistening, as well as an **increase of average harvested yields by 10-15%** is achieved at field scale (Varlev, Popova, Gospodinov, 1995).
- **The indicated advantages of surge furrow irrigation are a prerequisite for a high quality irrigation that in terms of technical and economical indexes is compatible with the other contemporary mechanical irrigation techniques.**
- **"Cut back"** (reduced inflow during post-advance phase in the lowest position 3**, Figs.6 & 7**), combined with **"a multi-set" furrow irrigation** for the upper two positions 1 & 2, proved to be a possibility to avoid run-off under furrow irrigation (Popova, Varlev, Gospodinov, 1994).

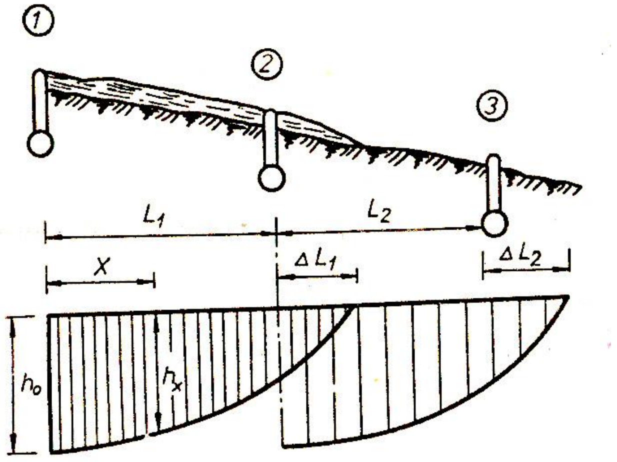


Fig.6. Application depth distribution along the furrows relative to "a multi-set" furrow irrigation.

Fig.7. "Multi-set" furrow irrigation at large field scale areas of 700 – 1000m length, when suitable furrows' length is 200-300m

3c. Substantial Water Saving achieved during surge irrigation Stage II:

Fig.8 illustrates the water saving advantages, achieved during surge irrigation experiment **(Stage II)** carried out in Stara Zagora. **Due to streams' interruption (with respective pauses), runoff at the furrows' tails (shown in hatching) is substantially smaller.** The duration of surges **"on"** & **"off"** time is **5 min**, while **Stage II** started at **10:50** and finished at **11:45**. The water stream (**1.5 l/s**) and consequent runoff diagram, represented in **"point-dash"** line for continuous irrigation, are shown as well. Hatching diagrams indicate the runoff streams at furrow tail relative to the respective four surges.

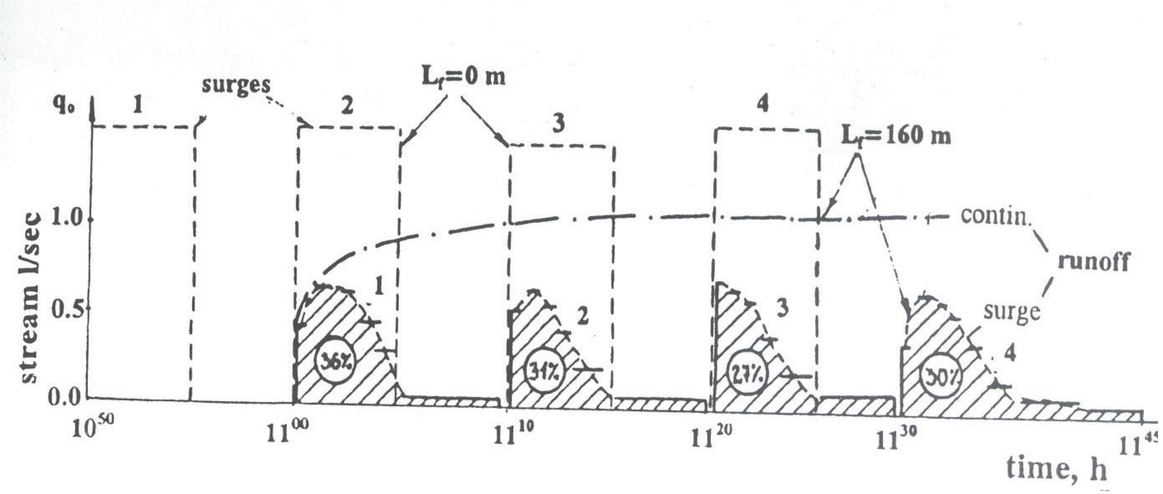
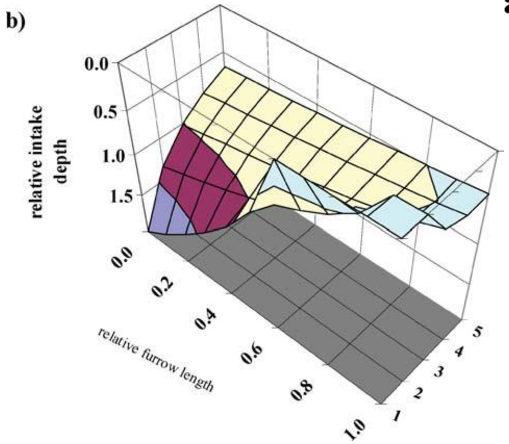


Fig.8. Diagram of streams delivered at the furrows' head and runoff at the furrows' tail under surge irrigation. The runoff under traditional continuous irrigation is shown in "dot-dash" line (Varlev, Popova, Gospodinov, 1998)

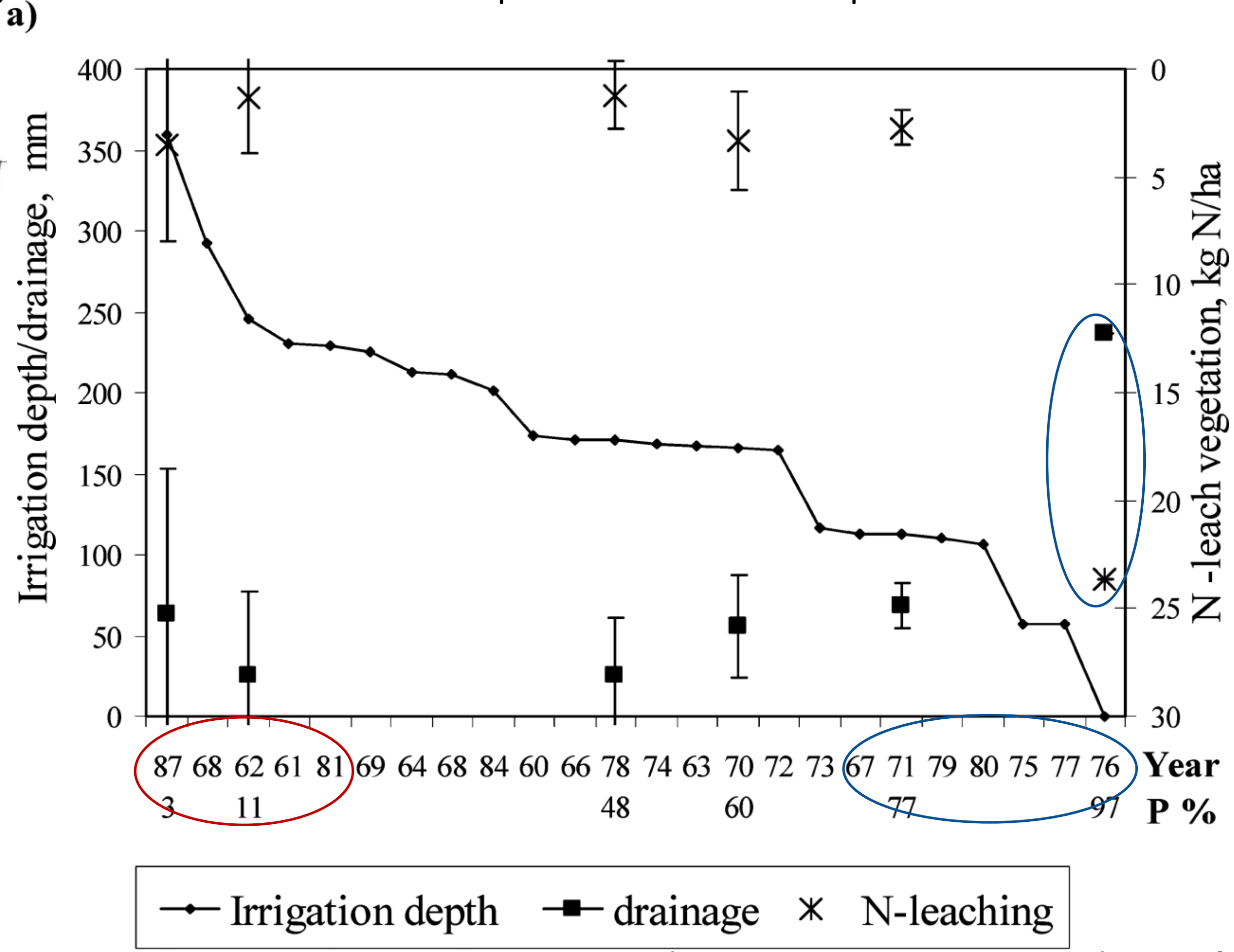
It is obvious that the percentage of runoff, relative to the volume of water delivered only during **Stage II**, is **30 %** on the average. If however this runoff is related to the total delivered water during **Stage I** & **Stage II**, the previously mentioned percentage will be reduced to less than **5 – 10%,** i.e. **runoff losses are completely acceptable** (Varlev, Popova, Gospodinov, 1998).

4. Model simulation results on "irrigation uniformity" case study

Fig.9 illustrates the water-saving and ecological impact of irrigation "**poor uniformity**" treatment (**b**) on the spatial variability of **seasonal (May-Sept) deep percolation** and **N-leach** (**a**) relative to maize crop grown under the conditions of a simultaneously irrigated furrows in a set at "Chelopechene" **EF** over the period 1960-1987.



During **dry years** (P_I <11%) the mean drainage over considered furrow set is from 30 to 70 mm(**STDEV**=98mm) and corresponds to a mean N-leaching from 4 to 5 kg N/ha.



During the "**moderately–wet**" period (**P_I=77-97%**) seasonal (May-Sept) drainage and N-leach are uniformly distributed over the furrow set at **STDEV=0**. The drier is the irrigation season, the larger are the losses of water and nitrogen due to the Nonuniformity of Irrigation depth distribution. An only exception of the rule is the year of extreme seasonal precipitation **1976** (**P_I**= 97%).

Fig.9. Impact of: **b)** irrigation "**poor uniformity**" treatment (**I** = 0, **Knun** = 1, **Cv** = 66%) and **a)**probability of irrigation depth (P_I) upon **mean** and **STDEV** of drainage and N-leaching totals for the May–September period, **1960-1987.**

5. Economically optimal uniformity of irrigation water application

•If irrigation is performed in time with a fully satisfactory water distribution uniformity over the irrigated area, **a maximum yield should be harvested under certain conditions** (i.e. soil fertility, crop variety, agro-technique and so on).

•When the same quantity of water is distributed with a certain non-uniformly, the average harvested yield should be smaller. If better distribution uniformity is aimed at, **a larger quantity of manual labour is required. Some equipment, materials and machinery are needed as well.**

•An economical criteria is formulated: "**Economically optimal is that Nonuniformity of irrigation water distribution that produces a minimal sum of lost production (due to non-uniformity of soil moistening) and labour cost for irrigation**".

•During years of different dryness of climate (**1951-2004**), i.e. different probability of occurrence - $\mathbf{P_{NIR}}$ (%), the water delivered for irrigation covers a different part of the total water required for a normal crop development (**Fig. 10**). **NIRs (mm) are smaller during "wet" years (P_{NIR} > 80%) that makes acceptable to distribute NIRs with a larger non-uniformity without causing any substantial yield losses. NIRs are larger in the "average" and "dry" years (P_{NIR}<75%) that requires to distribute them the best possible uniformity without causing any substantial yield losses.**

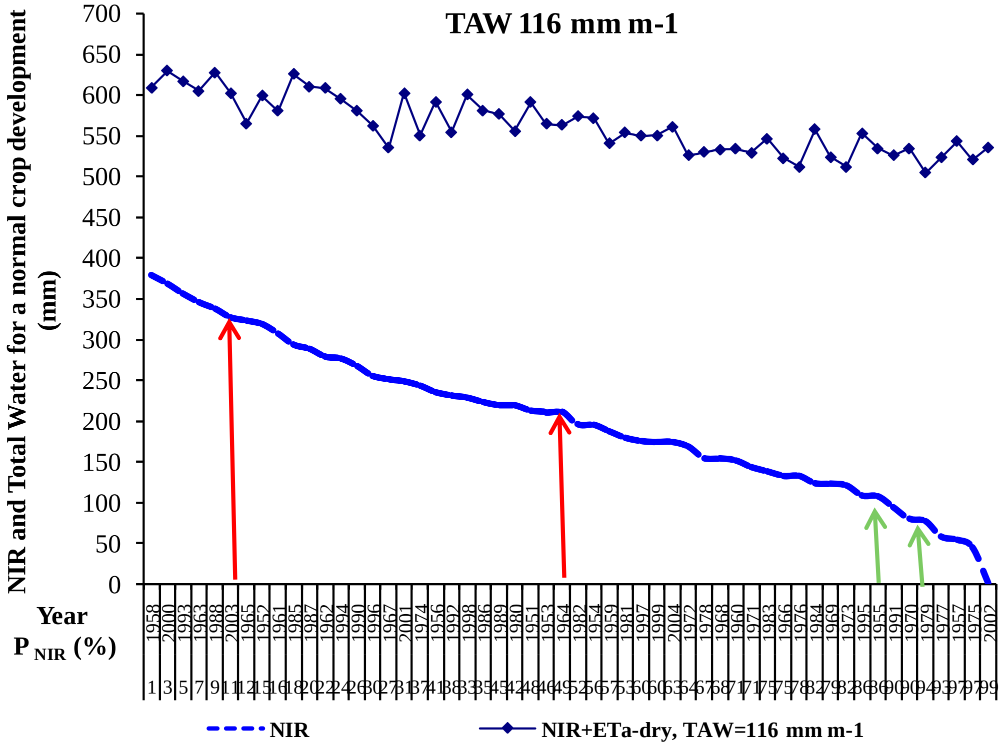


Fig.10 Probability curve of occurrence of a **Net Irrigation Requirements NIRs** (mm) and respective **Total Water Required** (**NIRs**+seasonal **ETa-dry**, mm) for a normal maize crop development during seasons of variable irrigation demand ($\mathbf{P_{NIR}}$) conditions, Pleven, **1951-2004.**

1. Surface irrigation over the world and in this country (Introduction)

- Considering the present enlarged population on the earth and the on-going processes of climate change and uncertainties, the importance of irrigation is supposed to increase substantially, while available water for irrigation is expected to get scarce (Alexandrov(Ed.)2011; Slavov et al, 2013; Moteva et al,2015; Popova&Pereira, 2008; Popova, 2010; Popova et al, 2011;2014; 2015).
- Surface irrigation has been a dominated practice worldwide, even when the remaining technologies, as sprinkler and drip irrigation, have a significant role for our society (Varlev, Popova, Gospodinov, 1998; Popova, Mailhall et al.2005). Thus, experts are those that are presently supposed to evaluate technical, economical and organizational advantages & disadvantages related to each water saving & environment protection irrigation practice and to determine the most suitable one regarding specific conditions.
- Considering the dominated Moderately-continental (The Danube plain and Sofia field) and Transitional-continental (The Thrace lowland) climate, irrigation application in Bulgarian Plains leads to a **1.6 – 2.1** larger crop productivity&economical efficiency comparing to the yield under rainfed crops (Varlev, 2011; 2012; Popova, 2012; Popova et al.2012; 2014). An important fact is also that irrigation mitigates yield variability over the different climatic years, which is a prerequisite for a stable economical development without risks in Bulgaria (Fig.1).
- The variability of rainfed maize yield in the **the Danube plain (30<Cv<55%),** is much lower then that in **the Thracian lowland (41<Cv<69%)** (Table 1), while under full irrigation conditions **Cv** drops to **17-18%** (Popova et al, 2011) **reaching 5-11% In Sofia field** (Popova, 2008; Popova and Kercheva, 2005).The contribution of irrigation for stable yields harvesting is also smaller **(15<Cv<25%)** in **Northern Europe.** The fact that irrigation is practiced under such climate conditions shows however that even in wet climate regions irrigation application is efficient.

The objective of present report is: to share a feedback on **quantitative water savings/environment protection achieved in Bulgaria**, using results of experimental trials and *validated simulation tools application at point & field scale*. The performance control is related to **improved furrow irrigation technologies by monitoring water application uniformity and efficiency under Traditional Continuous and Surge Flows as well as other water saving practices**.