INTERNATIONAL SCIENTIFIC JOURNAL

MECHANIZATION IN AGRICULTURE & CONSERVING OF THE RESOURCES

Issue 4
2016

Year LXII, ISSN print 0861-9638, ISSN web 2534-8450

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
BULGARIAN ASSOCIATION OF MECHANIZATION IN AGRICULTURE

PUBLISHERS

SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING

BUGLARINA ASSOTIOATION OF AGRICULTURAL MACHINERY

ISSN PRINT 0861-9638, ISSN WEB 2534-8450
YEAR LXII ISSUE 4 / 2016

The journal "Mechanization in agriculture & Conserving of the resources" is continuer of the journals "Mechanized farming" (1948-1957), "Mechanization and electrification of agriculture" (1959-1980), "Mechanization of agriculture" (1981-1991) and "Mechanization in agriculture" (1991-2016)

108, Rakovski Str., 1000 Sofia, Bulgaria
tel. (+359 2) 987 72 90,
tel./fax (+359 2) 986 22 40,
office@stumejournals.com
WWW.STUMEJOURNALS.COM

C O N T E N T S

MECHANIZATION IN AGRICULTURE

CONSERVING OF THE RESOURCES

THEORETICAL DETERMINATION OF CUTTING FORCE OF THE SUGAR BEET TOPS FROM ROOT CROP HEAD

ТЕОРЕТИЧЕСКОЕ ОПРЕДЕЛЕНИЕ СИЛЫ СЧЕСЫВАНИЯ БОТВЫ САХАРНОЙ СВЁКЛЫ С ГОЛОВКИ КОРНЕПЛОДА

DrSc., prof., eng., academician of the NAASU Bulgakov V. PhD [1],
Assoc. prof., eng. Boris M. PhD[2], Eng. Ihnatiev Ye.[3], Prof., doc., eng. Beloev H. PhD [4],

[1] National University of Life and Environmental Sciences of Ukraine
15, Heroyiv Oborony Str., Kyiv, 03042, Ukraine
[2] Podolsky State Agricultural and Technical University,
13, Shevchenko Str., Kamenetz-Podolskiy, 32300, Khmelnytsky region, Ukraine
[3] Tavria State Agrotechnological University,
18, Khmelnytskiy av., Melitopol, 72312, Zaporozhye region, Ukraine
[4]"Angel Kanchev" University of Rousse, 8, Studentska Str., 7017, Ruse, Bulgaria
E-mail: vbulgakov@meta.ua, tdatu-mvz@yandex.ru

Abstract: *Beet tops harvesting is a complex task of the sugar beet growing industry which forms the qualitative indicators of root crops during their further digging out from the soil and determines the loss of tops and sugar-bearing mass. In the development of theoretical foundations of the optimal tops cutting from heads of sugar beet root by different types of topping working bodies should take into account forces which act at the same time and the rational cutting height. Theoretical researches having been carried out hitherto concerned only the detailed analytical description of the functioning of the new designs of topping working bodies and practically did not concern the general provisions of the separation tops from the head of root crop. The aim of this study is the theoretical determination of the forces that occur at the contact point of cutting working body of topper machines with root crops head of sugar beet root crop. When carrying out theoretical studies are used the methods of mathematics, theoretical mechanics, strength of materials, methods of programming and numerical calculations on PC. As a result, of the theoretical research new analytical dependencies of force describing the processes of crumpling and subsequently cutting of sugar beet heads by topping working body, depending on the size and shape of root crops heads and design parameters of topper have been obtained. As a result, of numerical calculations on PC critical level value of penetration of the cutting element of topping working body into root crops head of sugar beet and maximum value of cutting force at which ejection of root vegetables from the soil doesn't take place, was defined. The obtained theoretical dependencies and values of normal reaction and cutting forces are the basis for the further working out of a mathematical model of dynamic interaction system of cutting working bodies with the heads of sugar beet.*

KEYWORDS*: ROOT CROP, BEET TOPS, HEAD OF ROOT, WORKING BODY, THEORY, CONTACT AREA, CUTTING FORCE*

1. Introduction

Sugar beet is one of the strategic industrial crops in the world. Sugar, beet pulp and green mass of foliage are useful products for humans and animals as well as feedstock for biogas production. The most difficult process in the production of sugar beet is its harvesting. First operation of this of technological process is cutting of beet tops from root crops heads on a root. The quality of the beet tops cutting from root crops heads is directly affect other harvesting indicators – even a small amount of tops residues on the root crops heads during digging up significantly reduces quality indicators of sugar beet. Having been conducted earlier researches showed that a low-quality tops cutting can reduce the quality of sugar beet roots per 10 ... 15%. Therefore, cutting the tops from root crops heads of sugar beet is a relevant scientific and technical task for beet industry.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

Such researchers as P.M. Vasilenko, L.V. Pogorelyiy, V.M. Bulgakov, P.V. Savich, N.V. Tatyanko et al. [1, 2, 3, 4] dedicated many works to the issues of theoretical and experimental research of beet tops separation from root crops heads.

2.2. Purpose of the study

Theoretical definition of the forces taking place at the point of contact of cutting working body of topper machines with a root crops head of sugar beet.

2.3 Materials and Methods

When carrying out theoretical studies methods of mathematics, theoretical mechanics, strength of materials, as well as methods of programming and numerical calculations on the PC was used.

3. Results and discussion

The equivalent scheme of interaction tops-cutting working body and head of sugar beet for carrying out theoretical studies was developed. Consider one of the most typical cases of such interaction when cutting working body penetrates by its front cutting edge into the upper part of the head of sugar beet. Let us represent sugar beet root as motionless object placed in the soil (Fig. 1). Upper part of root crops - the head is represented as a sphere of radius r, with a center in point O. Flat Cartesian coordinate system xOy has been drawn across the point O in where the axis Oy is directed vertically upward and the axis Ox is directed to the right. Sugar beet head starts interaction with cutting working body, represented as rectangular cross section, which moves translationally and penetrates into the body of the head of root crop. The front lower point of blade is denoted by C. Penetrated in the body of root crops head the cutting working body of rectangular shape has coordinates of its points C in the above mentioned coordinate system, denoted by x_c and y_c. Other dimensions characterizing interaction of sugar beet head and cutting working body are being denoted by r_x and r_y.

According to the results of preliminary experimental studies it was found that during the interaction with the head of root crop, when topping leaves bunch, cutting working body moves at a relatively small value. Preliminary studies of the kinematics interaction of cutting working body with sugar beet have shown that blade of working body have slight displacement distance and its absolute velocity is also changes slightly. And therefore this curvilinear arcuate trajectory with a sufficient degree of accuracy, is possible to replace with a straight-line trajectory.

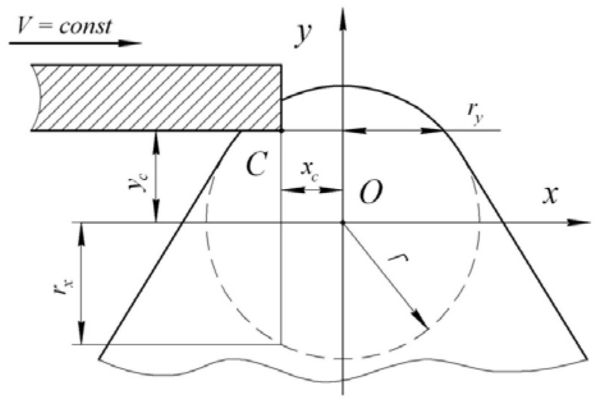


Fig. 1. *The equivalent scheme of cutting working body interaction with head of sugar beet when tops cutting*

Taking into account these circumstances, the assumption has been made that cutting working body interacting with the head of root sugar beet moves in a straight line at a constant forward speed *V* (Fig. 1) [6, 11, 12].

If at the initial moment of time, in this interaction, deformation of the upper layer of the head of root beet takes place then occurs crumpling. The increase of contact area of the front edge of the cutting working body with the root crop head after that takes place tension grows at a certain value of working body penetration into the root crop head body the final cut is carried out. Theoretically, this will happen when crumpling force exceeds cutting force of the rest of sugar beet root crop head, i.e. in compliance with such inequality:

$$P_s \geq P_c, \quad (1)$$

where: P_s – crumpling force of the root crop head; P_c – cutting force of the root crop head.

After that, let us determine the critical value of penetration of cutting working body in the root beet head and define its relationship with the values P_s and P_c.

Crumpling force will be determined by the current contact area F_s and permissible contact stresses of crumpling $[\sigma_s]$. For determine the crumpling force P_s well known dependency was used [7]:

$$P_s = [\sigma_s] F_s. \quad (2)$$

The contact area is determined by the area of the segment formed by a circle of radius r_x and the chord, which passes at a distance y_c from the axis *Ox* (Fig. 1):

$$F_s = \frac{r_x^2}{2}(\beta - \sin\beta). \quad (3)$$

where: β – sector angle formed by the segment with F_s area; r_x – radius of the circle, which has been obtained by the intersection of the sphere of the head of root with plane, which passes through the contact edge of the working element.

Angle sector β of crumpling area and circle radius r_x in the crumpling plane is determined from equation [5, 8]:

$$\beta = 2\arccos\left(\frac{y_c}{r_x}\right), \quad (4)$$

and

$$r_x = \sqrt{r^2 - x_c^2}, \quad (5)$$

where: r – sphere radius of the head of root beet.

Taking into account the value determined by (2 – 4), and on the basis of conducted algebraic transformations the dependence has been finally obtained for crumpling force P_s on the penetration value x_c of cutting working body into the body of the head and is represented in the following equation:

$$P_s = [\sigma_s]\left\{-\left(\frac{r^2}{2} - \frac{x_c^2}{2}\right)\left[\sin\left(2\arccos\left(\frac{y_c}{\sqrt{r^2 - x_c^2}}\right)\right)\right] - 2\arccos\left(\frac{y_c}{\sqrt{r^2 - x_c^2}}\right)\right\}. \quad (6)$$

Cutting force P_c of root crops head is determined by the cuts area F_c and permissible cutting force $[\tau]$ root beet head and it is equal to [7]:

$$P_c = [\tau] F_c. \quad (7)$$

Area cut F_c of root crops head is defined as the difference area of the circles formed by the intersection of the sphere by the cut plane and area of segment formed by radius r_y and chord, which passes at a distance x_c from the axis *Oy* (Fig. 1). We have:

$$F_c = \pi r_y^2 - \frac{r_y^2}{2}(\gamma - \sin\gamma), \quad (8)$$

where: γ – sector angle formed by a segment of area F_c.

The angle γ and radius r_y are defined by following equation (4) and (5):

$$\gamma = 2\arccos\left(\frac{x_c}{r_y}\right), \quad (9)$$

and

$$r_y = \sqrt{r^2 - y_c^2}, \quad (10)$$

Taking into account the value determined by (8 – 10), and on the basis of conducted algebraic transformations the dependence of crumpling force P_s on the penetration value x_c of cutting working body into the body of the head of sugar beet has been finally obtained (Fig. 1).:

$$P_{çð} = [\tau]\left\{-\left(\frac{r^2}{2} - \frac{y_c^2}{2}\right)\left[\sin\left(2\arccos\left(\frac{x_c}{\sqrt{r^2 - y_c^2}}\right)\right) - 2\arccos\left(\frac{x_c}{\sqrt{r^2 - y_c^2}}\right)\right] + \pi\left(r^2 - y^2\right)\right\}. \quad (11)$$

Substituting the value of expressions (6) and (7) in the inequality (2) it is possible to determine the critical penetration value x_c under root crops head cutting.

Thanks to the developed program for the PC the numerical calculations have been carried out and the graphics solutions of inequality obtained (2), taking into account the equation (6) and (11) are shown in Fig. 2 and Fig. 3.

The following values of initial parameters in the calculations were adopted: $[\tau]$ = 1.14 MPa [10], $[\sigma_s]$ = 3.0 MPa [9, 14, 15], r = 0.025 m, y_c = 0.015…0.025 m.

As can be seen from the obtained graphical dependences (Fig. 2) maximum cutting force P_c will be determined by the maximum value of crumpling force P_s of root crops head. The cutting force P_c will be equal to crumpling force P_s at the cutting height of root crops head being equal to 10 mm. At the same time cutting force equals to 820 N that is much higher than the permissible stability force of root sugar beet in the soil (Fig. 2). Obviously, the height difference *Δh* of contiguous working elements of cutting working body should not exceed 4 mm. The parameter value of kinematic coupling between the cutting working bodies *Δφ* = 2° is being determined on this condition basis. Thus, for further calculations is possible to accept the maximum cutting force *Q* = 200 N.

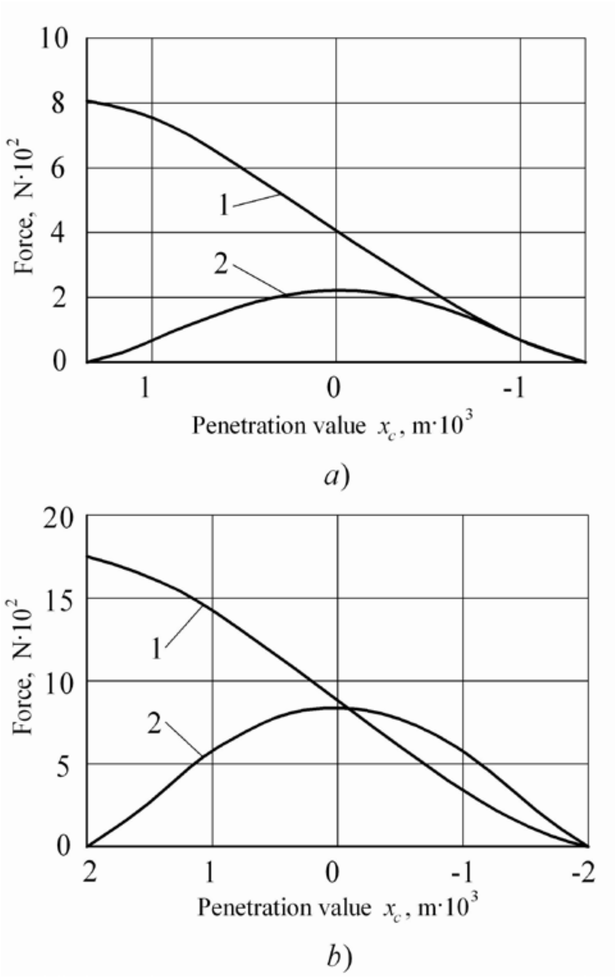


Fig. 2. Dependencies: 1 – cutting force P_c and 2 – crumpling force P_s from
height of cut Δh and the value of penetration x_c into the root crop head body:
a) Δh = 0,004 m; *b*) Δh = 0,01 m

Using the obtained dependencies (Fig. 2) the graphs of the total maximum crumpling force P_s of sugar beet head from the cutting height Δh have been worked out (Fig. 3). Thus in Fig. 3 the permissible crumpling force P_s is shown.

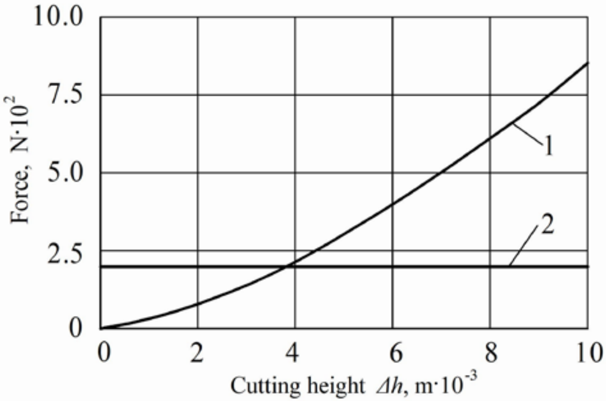


Fig. 3. Dependence of the total maximum force from the cutting height Δh:
1 – root crop head crumpling P_s; 2 – tops detachment from the root crop head

Analysis of the graphical dependencies (Fig. 3) shows that the maximum crumpling force P_s can be reached on the height of cut not more than 4 mm.

4. Conclusion

1. New analytical equations that describe the processes of crumpling and the subsequent cut of root crops head of sugar beets then separating the tops were defined.

2. Critical value of the penetration of the cutting part of topping working body in the root head, when there is no ejection of sugar beet out of the soil was found. Numerical calculations carried out on a PC enabled to determine its value Δh = 4 mm.

3. Maximum value of the cutting force Q equal to 200 N, was determined.

4. The obtained theoretical dependencies and values of normal reaction and cutting force *Q* are the basis for the further working out mathematical model of dynamic interaction system of cutting working bodies with sugar beet heads.

5. Literature

1. Bulgakov V.M. Teoriya sveklouborochnyih mashin. Monografiya / V.M. Bulgakov. – Kiev: Izdatelskiy tsentr NAU, 2005. – 245 s.

2. Vasilenko P.M. Osnovyi nauchnyih issledovaniy (Mehanizatsiya selskohozyaystvennogo proizvodstva) / P.M. Vasilenko, L.V Pogorelyiy. – Kiev: Vyisshaya shkola, 1984. – 266 s.

3. Vasilenko A.A. Kompleksnaya mehanizatsiya proizvodstva saharnoy sveklyi / A.A. Vasilenko, P.T. Babiy, P.V. Savich i dr. – Kiev: Selhozobrazovanie, 1962. – 243 s.

4. Pogorelyiy L.V. Sveklouborochnyie mashinyi: istoriya, konstruktsiya, teoriya, prognoz / L.V. Pogorelyiy, N. V. Tatyanko. – K.: Feniks, 2004. – 232 s.

5. Filchakov P.F. Spravochnik po vyisshey matematike / P.F. Filchakov. – Kiev: Nauchnaya myisl, 1974. – 743 s.

6. Targ S.M. Kratkiy kurs teoreticheskoy mehaniki: uchebnik dlya vyisshih tehnicheskih zavedenniyy / S.M. Targ. – Moskva: Vyisshaya shkola, 1986. – 416 s.

7. Pisarenko G.S. Spravochnik po soprotivleniyu materialov / G.S. Pisarenko, A.P. Yakovlev, V.V. Matveev. – Kiev: Nauchnaya myisl, 1975. – 704 s.

8. Vodnev V.T. Osnovnyie matematicheskie formulyi / V.T. Vodnev, A.F. Naumovich, N.F. Naumovich. – Minsk: Vyisshaya shkola, 1988. – 255 c.

9. Helemendik N.M. Povyishenie mehaniko-tehnologicheskoy effektivnosti trudoemkih protsessov v sveklovodstve: avtoref. dis. na poluchenie nauch. stepeni dokt. tehn. nauk.: spets. 05.20.01 / N.M. Helemendik. – Ternopol: TPI, 1996. – 48 s.

10. Helemendik N.M. Issledovanie tehnologicheskogo protsessa i rabochih organov dlya uborki saharnoy sveklyi v usloviyah Zapadnoy Stepi USSR: Diss. kand. tehn. nauk: 05.410 / N.M. Helemendik. – Voronezh: SHI, 1968. – 31 s.

11. Bat M.I. Teoreticheskaya mehanika v primerah i zadachah: uchebnoe posobie / M.I. Bat, G.Yu. Dzhanilidze, A.S. Kelzon. – Moskva: Nauka, 1973. – 488 s.

12. Butenin N.V. Kurs teoreticheskoy mehaniki. Tom 2 / N.V. Butenin , Ya.L. Lunts , D.R. Merkin. – Moskva: Nauka, 1985. – 496 s.

13. VISHOM. Fiziko-mehanicheskie svoystva rasteniy, pochv i udobreniy: metodyi issledovaniya, priboryi, harakteristiki. – Moskva: Kolos, 1970. – 417 s.

14. Vovk P.F. Agrofizicheskie svoystva korney saharnoy sveklyi v svyazi s mehanizatsiey uborki / P.F. Vovk // V sbornike: Teoriya, konstruktsiya i proizvodstvo selskohozyaystvennyih mashin. Tom 2. – Leningrad: Selhozizdatelstvo, 1936. – S. 269-284.

15. Tsarenko O.M. Mehaniko-tehnologicheskie svoystva selskohozyaystvennyih materialov: praktikum / O.M. Tsarenko, S.S. Yatsun i dr. – K.: Agrarnoe obrazovanie, 2000. – 93 s.

16. Lammers P.-S. Harvest quality of six-row sugar beet tanker harvesters / P.-S. Lammers, M. Rose // Landtechnik. – 2005. – №60., H. 5. – P. 252-253.

17. Huijbregts T. Long-term storage of sugar beet in North-West Europe / T. Huijbregts, G. Legrand et al. // COBRI report. – 2013. – №1. – 54 p.

18. Przybył J. Method of external assessment of the quality of sugar beet roots / J. Przybył et al. // Agricultural engineering. – 2013. – Z. 4., T. 2. – P. 113-125.

THE PECULIARITIES OF THE WORK OF TILLAGE MACHINES ON THE SLOPING LANDS

Candidate of Technical Sciences, Associate Professor Viktor Pryshliak
Ukraine, Vinnytsia National Agricultural University
viktor.prishlyak@i.ua

Abstract: *Considered are the problematic issues of tillage on slopes and presented the methodological aspects of theoretical analysis and experimental research. The production testing of the work of tillage equipment in the circumstances is being taken into account for the conservation of soil fertility. It is considered that the ploughs are often used on sloping lands for primary tillage, although the use of special tools for subsurface of the soil conservation tillage is preferable. Given here are the scientific-theoretical and practical recommendations on the use of the complex contour tillage machines and drainage system in the agriculture fields with complex terrain.*

KEYWORDS: *SOIL, CROPS, CROP ROTATION, TILLAGE MACHINES, EROSION.*

Introduction.

The development of tillers is inextricably linked with the zonal features of their use, where the important place is occupied by the difficult terrain conditions. Tillage processes on the horizontal sections at the optimum values of humidity and hardness of soil by existing machines are performed generally satisfactory. However, the work of soil-cultivating units is carried out not only on the flat fields, but also on slopes up to 5-7˚. The machine and tractor units with static stability margin about 35-40˚, may work with high quality in the fields with a slope just before 2-3˚. In hilly areas with steep cross slopes exceeding the specified value, due to the lack of special equipment for working in difficult terrain conditions, to carry out high quality production processes is not possible. In Ukraine, more than 95% of arable land is located on slopes up to 5˚, and the rest − 5-14˚. In some regions of the country the slopes which are steeper than 5˚ have a significant share − more than 20-40% [1].

Prerequisites and means for solving the problem.

Working conditions of agricultural machines on the same field with the hilly terrain vary depending on the direction of the movement: uphill, downhill, across a slope or hillside. From the point of view of minimizing erosion in sloping lands the movement of the tillage machines should be carried out across the slope.

However, it should be borne in mind that when driving across a slope there is a spontaneous withdrawal of tires caused by the lateral component of the force of gravity units, as well as the difference in rolling resistance forces of the upper and lower support elements along the slope unit. Disposed along with spontaneous slipping, occurs sliding of the machine wheels and its working bodies down the slope, which depends mainly on the magnitude of the angle of the slope, the load on the wheels, the physical and mechanical properties of the soil and the tire grip. As a result of the combined action of the side movement and sliding is broken the rectilinear motion of sustainable agricultural machines on a slope.

When the tillers are working on sloping lands, along with the stable movement should be considered the quality performance and especially the agro ecological ones. For example, when ploughing on slopes steeper than 4º occurs the displacement of soil up the hill, partial wrapping layer of soil by a plough body, and when working with soil turning to the base of the slope there is its shift to the bottom, which is adequate to the soil loss of 12 m^3/ha [1, 2].

In general, the quantitative assessment of erosion processes is given for the intensity of soil loss per unit area and per unit time, i.e. t/ha per year or mm/year. In these units is measured the rate of soil processes too. Comparing the rate of the soil loss with the rate of the soil formation, it is possible to have an estimate of the degree of danger of erosion. And if the intensity of erosive processes is below than the rate of soil formation, then the erosion of this field is not dangerous, although this is very rare.

Solution of the examined problem.

In conservation agricultural system with the contour-reclamation land use, the organization of the territory is depending on the steepness of the slopes which are differential by nature, according to which the arable land is divided into 3 groups. The first group of land − plain and slopes up to 3º. It is used for grain and other agricultural cultivated between rows crops, rotation of grain cultures. In farmlands with very rugged terrain is envisaged the reduction of cultivated crops and increased the amount of grains and herbs. This is due to varying soil protection efficiency of these crops. The second group of land − slopes from 3 to 7º. They are recommended for the use of catch crop rotations with the sowing of winter cereals and ardent, annual and perennial grasses and without row crops. The third group of land − more than 7º slopes. They are seeded by perennial grasses. The complex of the used tillers depends on the type of the growing crop, the sowing of which in turn depends on the steepness of the slope.

According to the profile of the slopes they can be divided into concave, convex and convex-concave. In the concave slope steepness gradually diminishes from the middle of the sole. The soil on it becomes more fertile as you approach the valley. A convex slope has relatively level ground at the top, it is lowered below the surface and in the lower part moves sharply into the valley or ravine. On the convex-concave slopes the steepest portion is spaced at some distance from the base. Over the steep part of the slope is again a flat area on which is deposited the fine earth, carried by the upper part of the slope with water or mechanical action supporting-running elements of tractor units.

For traffic conditions of the tillage machines by contours on the convex-concave areas of the slope change in the thickness of the fertile layer equals [2]

$$\Delta h_i = h_0 (1 - \frac{Y}{B_n}) \pm [1 - \frac{R_i}{R_i + Y}],$$

where h_0 − the initial thickness of topsoil; Y − distance movement of soil during processing; R_i − the radius of curvature at the point where the value is determined Δh_i; B_n − the bandwidth that is being processed. The "+" is used for the convex, and the sign "−" for the slope of the concave sections.

The intensity of the mechanical-technological erosion increases in proportion to the increase in the steepness of the slope α. If the main line of the slope is represented by a straight line and the value of α along the main line is constant, the velocity v and the displacement of soil along the (main line) generator are also constant. On the convex-concave areas, which occupy an important place in agriculture, the steepness of slope α on convex sections along the generators increases and decreases in concave areas. This affects both the stability of the machine movement, especially in the transverse direction of the slope, and the displacement of soil erosion particles downward the slope.

The surface of the field sloping lands include rocks, big pieces of land, macro- and microscopic irregularities. The particular importance is after their ploughing. From the bottom of the slope the surface of its own parts and where the macro roughness increases due to the steepness of the slope. At the same time there is a movement of smaller parts for large deviations. Considering the frictional force differential equation of motion of the material particles along an inclined plain takes the form [4]:

$$m\frac{d^2 s}{dt^2} = m\frac{d\text{v}_{\text{п}}}{dt^2} = mg\sin\alpha - fmg\cos\alpha, \qquad (1)$$

where m – the mass of the particle; s – the way; t – time; v_n – speed; g – acceleration due to gravity; f – coefficient of friction.

Integrate the equation (1) twice with the initial conditions $v_n = v_o$; $s = 0$ when $t = 0$, we obtain

$$s = \frac{\cos\varphi}{2g\sin 9(\alpha - \varphi)}(v^2 - v_0^2),$$

where φ – is the angle of friction.

For the case $\varphi > \alpha$, the particle stops after a certain period of time:

$$t = t_1 = -\frac{v_0 \cos\varphi}{g\sin(\alpha - \varphi)} = \frac{v_0\cos\varphi}{g\sin(\varphi - \alpha)}.$$

The path that the particle will take place at the same time is equal to:

$$s_{\max} = \frac{1}{2}\frac{v_0^2\cos\varphi}{g\sin(\varphi - \alpha)}. \qquad (2)$$

At the same time

$$s = \frac{h}{\sin\alpha}, \qquad (3)$$

where h – height to which the piece moves as it moves along the inclined plain until it stops.

Then, taking into account (2) and (3) the height to which a particle moves under the effect of the lateral component $mgsin\alpha$, can be represented in this form

$$h = \frac{1}{2}\frac{v_0^2\sin\alpha\cos\varphi}{g\sin(\varphi - \alpha)}.$$

On the plain, the angle of which α < φ, the body cannot slide under the action of gravity, since the value of the friction will be more $fGcos\alpha$ term by $Gsin\varphi$ plain. Such a plain where the angle is less than the angle of friction is called self-locking.

Mechanical and technological erosion indicator for changing the thickness of topsoil Δh_i most intensively occurs in areas with convex contour and a convex manner.

In crop production technologies, the soil feels the impact of different working units and support-running elements of technical means of mechanization. The most energy-intensive process step is ploughing, which has long been very common in the farming system and was considered the primary tillage operation. Ploughing has some advantages and disadvantages [3].

When ploughing on sloping lands reservoir turn leads to destruction of protective vegetation cover of the soil, plant residues, which protect the structure of the soil from the devastating impacts of raindrops. Plant residues located on the surface of the field reduce the speed of displacement of soil particles with melting or rain water, which reduces erosion.

As known, the condition of the stable position of the soil layer during ploughing by ploughs which are not equipped with skimmers is the following:

$$\frac{b}{a} = k \geq 1{,}27,$$

where b and a – respectively, the width and thickness of the reservoir.

Limit value width to thickness ratio for formation on slopes depend on the field angle of inclination α and increase in the steepness of the slope value k_l increases. For example, with increasing steepness of the slope α from 0 to 5º limit steady position of the formation k_l increases from 1,27 to almost 1,33. This means that at constant widths body of plough, a ploughing depth should be reduced to achieve the desired quality of primary tillage.

When the ploughs work on the slopes, the special interest is the transverse stability of plough-body movement in the soil, which is the main source of friction landside of the furrow wall. The lateral component of the soil reaction on the working surface of the plough-body, taking into account the steepness of the slopes can be expressed by the formula:

$$R_y = R_x ctg(\gamma_0 + \varphi) + G_i sin\alpha,$$

where R_x – soil resistance force acting on it in the body of the plough layer cross-sectional plain; γ_0 – the angle between the blade and coulter groove wall; φ – angle of friction of the soil on the working surface; G_i – gravity of the plough, per one case.

The length of the landside is determined from the condition for sustainable progress of the plough in the horizontal plain and unloading racks housing the bending moment. For multihull ploughs landside length can be determined by the formula

$$l = \frac{b_к \cos\varphi}{2\sin\gamma_o\cos(\gamma_o + \varphi)},$$

where $b_к$ – the width of the body; φ – angle of friction of the soil on the steel; γ_o – the angle between the blade and coulter field edged body.

To combat water erosion devices used to plough for the formation of holes, discontinuous furrows, ridges and other. The device for the formation of holes consists of a section with the hole-formation device and special hinge mounted on the plough frame at an angle of 55º to the direction of thrust. When creating oval holes on the field surface are formed oval holes, totaling 200-300 m^3 per 1 ha, which corresponds to 12-13 thousand. A hole length of 1,1-1,2 m and a width of up to 0,4-0,5 meters. Ploughing while making can be effective on side slopes 4-6º.

Cultivation of the soil without turning the soil formation, is widely used in soil conservation technologies of land processing includes such operations: metal-cutting blades, surface treatment, treatment of the combined units, chisel tillage, chisel processing, slotting, milling, deep-hole digging.

Metal-cutting blades tools better perform their function in the light and medium soils. On heavy soils they work worse, form a lump, don't move steadily. For quality work of metal-cutting blades tools the soil should not be over-wet. On heavy soils and at higher moisture content is recommended a wider use of rippers and chisel cultivators, gaps-maker, narrow holes tools, cutters.

When designing metal-cutting blades, you can implement a large number of options for the location of the working bodies, as the soil formation at work does not move to the side and does not turn around. But because these tools work on stubble backgrounds, containing a significant amount of crop residue on the field surface, it is important that the distance between the paws was enough for the free passage of plant debris and carrying out the process without jamming the soil.

Soil treatment without recourse to the reservoir was carried out with a chisel ploughs working bodies in the form of rippers with interchangeable bits of different designs. As a result of deep soil loosening and mixing 20-30 % of crop residues from the surface the ball 2-3 times increased its water soaking that prevented water erosion. Chisel hoeing to a depth of 50 cm was carried out during the rotation. Because of the depth of treatment below the arable layer of the energy intensity of the process of loosening the soil increased sharply.

A chisel tractive resistance P and other tools which loosen the soil to a depth that does not exceed the critical cutting depth can be determined by the formula [4]

$$P = fG + (k + \varepsilon v^2)S_k,$$

where f – coefficient of moving tools in the furrow; G – gravity gun; k – soil resistivity; v – working speed; S_k – sectional area of the loosened soil.

On sloping lands the system of the non-plough tillage included slotting the soil to a depth of 60 cm, with gaps of 3-4 cm in width and the distance between them more than 120-150 cm. The working bodies of the narrow holes maker worked in a cutting blocked mode.

Economically feasible is the use of combined units, which consist of a set of tools and execute within a single pass three or more basic operations – cultivation, disking of the soil, leveling, harrowing, compacting surface, etc. Each of these tools can be used individually for the intended purpose. Needle harrow BIG-3, for example, effectively loosens the soil in the spring to perennial grasses of the 2nd, 3rd year of cultivation.

The most beneficial to have the stabilization of movement for the tillage equipment which is carried out by the lateral soil reaction on the working bodies of the machine and wheels. Dimensions of the running wheels of tillers depend on soil conditions, implements design features, durability requirements.

A wheel experiences a radial load P_r and axial force P_o, applied to the bottom of the rim by the gauge. The magnitude of the axial force can be taken as

$$P_o = P_r \varphi_c,$$

where φ_c – friction coefficient. The axial force P_o creates point $P_o D/2$, which acts on the wheel, causing a bending stress. To increase traction with the ground applied spurs or flanges.

Pneumatic wheels mounted on the soil cultivated tools compared over metal ones have several advantages: they have somewhat lower traction resistance; they are less damaging to crops. Furthermore, application of pneumatic tires can improve speed and durability of the machine unit, due to the decrease of intensity shocks and bumps. Besides the tread of the tire must meet the following requirements: a good longitudinal and lateral grip on the rolling surface, sufficient self-cleaning grooves.

The above written scientific principles have important prerequisites for research and development activities of agronomic problems crop on fields with difficult terrain of crops, including promising bioenergetics groups − sugar beet, corn, wheat, triticale [5].

Results and discussion.

In all soil protection technology is appropriate to include measures which are related to improving soil fertility by application of organic and mineral fertilizers. Therefore, the development of tillers on slopes should be considered as an opportunity to make fertilizer, organic mulch, as well as to perform the processing of the soil environment, including siderites and other crop residues.

Conclusion.

The theoretical and experimental studies have made it possible to clarify certain provisions of the peculiarities of soil cultivation on slopes, and to obtain new scientific results in this direction. In particular, the theoretical substantiation system tillers, their interaction of working organs and working elements running with the soil, taking into account the conservation of soil fertility. Soil treatment without rotating layers of the ground 2-4 times reduces the soil erosion. It was found that as the primary tillage can be used a variety of processing till methods across slopes with hole-making along each 5-6 m at a depth of 50-60 cm.

References

1. Amelchenko P.A, Ksenevich I.P., Guskov V.V., Yakubovich A.I. Wheeled tractors on slopes. – M .: Engineering, 1978. – 248.
2. Zaika P.M. The theory of agricultural machines. T. I (Part 1). Machines and tools for cultivation. – Kharkov: Eye, 2001. – 444.
3. Bondar S.M., Pryshlyak V.M., Shymko L.S. Management of complex machines in manufacturing processes cultivation: monograph. – Nizhyn LLC "Publishing" Aspect-Polygraph ", 2015. – 524.
4. Vasilenko PM. The theory of particle motion on rough surfaces of agricultural machines. – K .: UASKHN, 1960. – 284.
5. Pryshliak Viktor. Study of physical and technological processes of planting crops on slopes of priority agricultural crops in bioethanol industry / MOTROL: Motoryzacja i energetyka rolnictwa, An international journal on operation of farm and agri-food industry machinery. – Lublin–Rzesów: Mot. and Energ. Rol., Commission of Motorization and Energetic in Agriculture, 2013. – Vol. 15, No 5, 181-187.

UNIVERSAL DEVICE FOR IMPROVEMENT OF SEEDERS FOR OPERATING IN A REDUCED TILLAGE MODE

УНИВЕРСАЛНО УСТРОЙСТВО ЗА УСЪВЪРШЕНСТВАНЕ НА РЕДОСЕЯЛКИТЕ ЗА РАБОТА ПРИ НАМАЛЕН БРОЙ ОБРАБОТВАНИЯ НА ПОЧВАТА

Principal assistant Bratoev K.P.
Assoc. prof. Mitev G.V.
“Angel Kanchev”University of Ruse – Ruse, Bulgaria
kbratoev@uni-ruse.bg
gmitev@uni-ruse.bg

Abstract: *The technological processes in growing crops follow specific sequence and every diversion from the quality indicators leads to unintended negative consequences. Sowing is a continuation of the pre-sowing soil treatment, which, in its turn, is a continuation of deep ploughing. In conventional farming, a number of advantages of deep ploughing can be lost unless an appropriate pre-sowing soil treatment is applied, followed by laying the seeds in the ground under optimal conditions.*

In the cases, when the choice of technology for growing and harvesting row crops, and more specifically, the type of tillage applied, is a result of analysis of physical, mechanical, chemical and biological properties of the soil, a reduced number of soil treatments can be suggested, or, in some cases, even implementing the subsequent technological processes after no till treatment.

A great number of farmers do no not possess the technological set of machinery for implementing innovative technologies. In such cases, the possibility of quick reconstruction of existing machinery, which should be able to operate following different technological sequence. Sowing is the most important of all technological processes and the preparedness of seeders to work in an integrated mode is of extreme importance, so that the can meet the challenge of reduced number of soil treatments.

KEY WORDS: *TECHNOLOGICAL PROCESSES, BASIC SOIL TREATMENT, SOWING, SEEDERS.*

1. *Introduction*

One of the most important and responsible moments in the technology of growing row crops is the pre-sowing soil treatment and the sowing. The activities of preparing the sowing resources and the sowing itself are inseparably linked. Pre-sowing soil treatment should take into consideration the requirements of the different crops. Otherwise, correct sowing would not be possible.

To perform correct sowing, the soil should be in a good structural condition: - for winter crops, optimal size of soil aggregates should be achieved, including staid soil, sufficiently moistened or completely dry, but not “dappled”; - for spring crops, the final loosening should be done immediately before sowing and at a depth, where the seeds will be laid. Contemporary industry offers a large selection of sowing machinery, under the common name seeders, [2]. The seeder is used after pre-sowing soil treatment. Usually the seeders are used for sowing only, regardless of the fact that levelling harrows can be attached to some of them, or press wheels are mounted on others. There are seeders that do the sowing without pre-sowing soil treatment such as:

Seeders for direct sowing — a coulter for opening a furrow for laying the seeds is mounted before the sowing apparatus;

Combined seeders — these machines are mostly designed for sowing, but they contain other organs, so they can perform several operations:

pre-sowing soil treatment + sowing

pre-sowing soil treatment + sowing+ fertilising

pre-sowing soil treatment + sowing+ fertilising+ plant protection (treatment of the crop after sowing)

Traditional seeders are generally two types:

Seeders for merged sowing (drills). They have a simple structure — a seed basket, mechanisms for adjusting the sowing rate and sowing depth, seed pipes and sowing bodies and markers for obtaining garnished sowing.

Seeders for precise sowing of row crops. They have a more complex structure — most often several sowing sections, each with a seed box, sowing disks for precise owing, sowing „heels“ and gauging press bodies. The common part is an apparatus for vacuum or pressure, conducted via pipes to each sowing section and markers for obtaining garnished sowing.

The agro-meteorological conditions in our country often require a significant number (5÷6) soil treatment operations in order to achieve quality pre-sowing soil treatment. The modern trends for performing these operations are directed to combining soil tillage and sowing operations by using combined tines and machinery [2].

A common situation before sowing row crops is the formation of soil crust in the fields, as well as the presence of plant residue. To deal with such situations, the working sections of modern seeders increasingly combine tilling working body, followed by a disc type sowing boot. Usually, the tilling working body is of the passive type, simultaneously loosening the soil and levelling the field micro profile. It is known that the disc boots work better when there are more chunks and plant residue. A characteristic moment in the performance of the first working body is the formation of the so called soil hill in front of it, which is a prerequisite for significant increase of its traction resistance. Replacing these passive bodies with needle discs is quite an appropriate technological solution of this problem.

2. *Prerequisites and ways of solving the problem*

The needle discs (fig.1) are a familiar type of tilling bodies, used in the so called rotary hoes. They are used for loosening the soil, destroying the soil crust and removing the weeds. These processes are the result from the rotation of the discs, stemming from their grip with the soil, while each needle of the discs interacts with it.

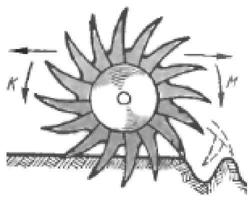


Fig.1. *Cultivator disc with sickle pins*

On the basis of the advantages of the needle discs, a cultivator section that is attached to each working section of a seeder for precise sowing with double rows has been developed. (fig.2).

In the structure of the cultivator section, two working parts have been incorporated. The first one consists of two cleaning needle discs, mounted by a clamp to the spring pole of the fertilizer boot. A shoulder, on which a battery of four profiling needle discs has been mounted, is hinged to the clamp and makes the second working part. The discs of the first part have a diameter of 300mm and are arranged at an angle of attack 25^0. In the second part, the discs have a diameter of 250mm, and are arranged parallel to the direction of movement of the seeder. All disks are 10mm wide.

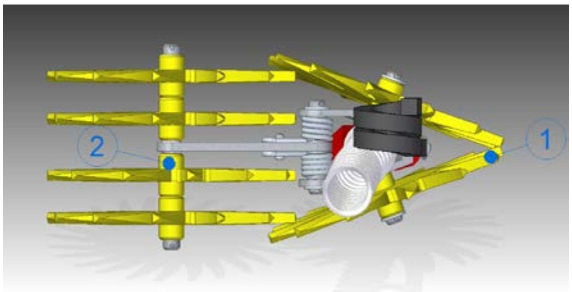


Fig.2. *General view of the cultivator section: 1 – cleaning discs; 2 – profiling disc battery*

The construction allows each disc to rotate relatively to its rotation axis, thus providing a more aggressive (direction M, fig. 1) or a gentler mode of working (direction K, fig. 1), depending on the conditions of work. The symmetrical construction of the cultivator section eliminates the need to perform specific adjustments for it to work.

The main accents in the design of the six cultivator sections are:

- Possibility to work at a certain depth;
- Forming a strip of soil in front of the sowing section, meeting the agro-technical requirements.

3. *Results and discussions*

As an output requirement for justifying the depth of work the information model "sowing section – field" is used [1]. According to this model, the minimum depth of tillage can be expressed as:

(1) $$a = 3\sigma + \Delta a,$$

where 3σ is the minimum diversion from the average value of unevenness of the field micro profile;

Δa - supply of treated soil area, considering the inertial disturbances during work, cm.

Through preliminary research on the micro profile of a field, at the end of the winter after strip till loosening of the soil, the deviation obtained is $\sigma = 2{,}51$. The supply of treated soil area Δa should be 1,5cm [1].

After substitution in formula (1) the minimum depth of pre-sowing treatment obtained is:

(2) $$a = 9{,}03 \approx 9\ cm$$

The main tasks of the discs from the first working part are: soil treatment at the required depth and removal of plant residue. To check the fulfilment of the first task the following condition is used:

(3) $$Q_z \geq F,$$

where Q_z is the vertical loading force applied, N;

F - is the force needed for soil deformation, N.

The soil deformation force is determined by the formula for the coefficient of volume crushing of the soil, presents as:

(4) $$S.a.q = F,$$

where S is the contact area of the needles, located in the working section of the disc, cm^2;

a - depth of treatment, cm;

q - volume crushing of the soil coefficient N/cm^3

For a disc with 30cm in diameter and depth of treatment corresponding to equation (2), the working sector of the disc is of 132^0 central angle. Thus, during work, three of the twelve needles of each disc will be in this sector of the disc, with contact area 9,5cm^2. According to reference data [2], the mean coefficient of volume crushing of the soil (q) in untreated soil with plant residue is $17{,}5\,N/cm^3$. According to these data from equation (4) for F is obtained :

(5) $$F = 1496{,}3\ N \approx 1500\ N$$

According to the technical characteristics of the seeder, for the vertical load force applied on each disc we obtain:

(6) $$Q_z = 1635\ N$$

Equations (5) and (6) show that condition (3) has been fulfilled and the discs will be able to work at the depth determined by equation (2).

Arranging the front discs under angle of attack of 25^0 is aimed at forming a strip, clean of plant residue, whose width corresponds to the width of the sowing section, which is 22cm.

To determine the width of the clean strip of soil, which the discs can form, we use the equation:

(7) $$b = 4.R.\sin\alpha.\sin\frac{\beta}{2},$$

where R is the radius of the needle disc, m;

α - the angle between the tangent point of the disc with the soil and the vertical diameter of the disc;

β - the angle between the two needle discs.

With disc diameter of 30cm and depth of tillage 9cm , the angle α is equal to 66^0, and the argument $\frac{\beta}{2}$, corresponds to the assigned angle of attack of the discs, i.e. 25^0. Thus, for the width of the strip, determined by equation (7) we obtain:

(8) $$b = 0{,}23\ m$$

The result (8) shows that the disks can form a sufficiently wide clean strip in front of the sowing sections.

The main function of the disks from the second working part of the cultivator section is to crush soil aggregates additionally and to level the profile of the strip tilled.

As a prerequisite for a more intensive impact of the needles, comes the choice of discs with a smaller diameter than those in the first part of the cultivator section. This is related to reducing the step between the needles of the disk, which, in its turn, leads to increasing the number of their penetration in the soil for a unit of distance (9).

(9) $$k = \frac{1}{X_z},$$

where X_z is the step of the needle, m.

The disc battery consists of four needle disks, spaced at equal distance from each other and thus providing working width of the disc battery of 20cm.

The work of the second part of the section has been checked through a laboratory experiment. The size distribution of soil before and after the treatment with the disc battery has been studied at a covered soil canal. According to the agro-technical requirements [2], the quantity of soil aggregates sized under 50 mm should be no less than 75%. Using sieve classifier, it has been determined that before the treatment with the disc battery, the quantity of soil aggregates, sized under 50 mm is 55%. After the treatment with the disc battery at a speed of 7k m/h and absolute humidity of the soil 14%, the quantity of soil aggregates sized under 50 mm has increased to 95 %.

A coefficient of variation is used as a criterion for estimating the levelling of the strip tilled. The results from the experiment, conducted in the same soil canal, show that after the treatment of the cultivator section, the profile of the 10 m strip is with a coefficient of variation 6,2 %. The value obtained is smaller than 7 %, allowed when the levelling of the field surface after the treatment [3].

Fig.3. *Field, treated with strip till machine and not tilled before sowing*

Fig.4. *Field sowed by advanced seeder for row crop after a single tillage in the autumn with strip till machine.*

4. Conclusion:

1. The seeders for row crops can be improved for working with reduced number of soil treatments by installing a battery with needle discs.
2. The percentage of soil aggregates sized under 50 mm is 95%.
3. The battery with active needle discs forms a strip 0.30 m wide at the depth of 60 mm and provides a suitable seedbed.

The paper has been developed under project AGR0042.20140328 "Conserving Bulgaria's Soils" funded by America for Bulgaria Foundation.

4. Литература

1. Демирев Ж. Обосноваване на дълбочината на почвообработка и технологичен процес на засяване на рапица.// Механизация на земеделието, 2013, брой 2, стр. 11-12, ISSN 0861-9638.
2. Демирев Ж., К. Братоев. Земеделски машини I. Русе, ИИЗЗ, 2012, ISBN 978-954-91147-9-9.
3. Сабликов М.В. Сельскохозяйственные машины. Москва, Колос, 1968

THE STATUS OF TRACE ELEMENTS IN SOILS ON ORGANIC AND CONVENTIONAL FARMS IN SERBIA

Prof. Dr Manojlović M., Prof. Dr Bogdanović D., Assis. Prof. Dr Čabilovski R., M.Sc. Marijanušić K.
Faculty of Agriculture – University of Novi Sad, Serbia
E-mail: maja.manojlovic@polj.uns.ac.rs

Abstract: *The aim of the research was to compare the impact of organic and conventional farming systems on soil quality with respect to trace elements (TEs) status. A study was carried out on seven pilot farms located in Vojvodina, the northern part of Serbia. The investigation was conducted at three representative farms certified for organic production and four conventional farms, in total on 96 production fields with different history of farming practices. Total and plant-available concentrations of TEs (DTPA) were determined in soil samples taken from 0-30 cm depth. The concentration of TEs was measured by atomic absorption spectrometer (AAS).*

Keywords: TRACE ELEMENTS (TEs), TOTAL CONCENTRATION, PLANT-AVAILABLE CONCENTRATION, ZINC (Zn)

1. Introduction

The concentration of trace elements (TEs) in soil is an indicator of possible excesses or deficiencies for plant nutrition, animal and human health and also environmental quality. Conventional agricultural production is characterized by intensification and high input of fertilizers and pesticides, which can cause both - TEs deficiencies (due to increasing demand for one or few TEs), or high accumulation of TEs (due to unbalanced fertilization and improper use of pesticides). Although risk for accumulation of TEs in soil is smaller in organic farming compared to conventional, the monitoring of these soils is important and has benefits.

Organic agriculture in Serbia is characterized with constant growth of areas under certified production. Number of organic producers and the area under organic farming systems are constantly increasing due to growing market demands for healthy and safe food. It is estimated that more than 10000 ha are under organic systems.

Our previous results (Manojlović et al., 2011; Manojlović and Čabilovski, 2011) did not show significant differences in the soil fertility between organic and conventional production in average for the investigated sites, as short period of transition to organic production (2-4 years) was not long enough that the positive impacts of organic production are reflected in soil fertility. Optimum to high soil fertility, determined in average for all tested sites in organic production, indicating good natural conditions necessary for successful organic farming in Serbia.

The results of the analysis of soil, food and feed samples from Vojvodina, northern part of Serbia (Čuvardić et al., 2006) showed high variability in the concentrations of essential and toxic trace elements between some locations in Vojvodina Province. Low concentrations of available microelements (Zn, Cu, Fe and Co) in soil and alfalfa samples were measured in soils with low texture as well as those with high pH-value and content of calcium carbonate. High total contents of Cu, Ni, and Cr in soil, as well as high content of Hg in alfalfa, found in some locations, indicated a necessity of monitoring their contents in soils and plants. However, later studies showed that TEs concentration was increased on micro-locations due to either geochemical factors or industrial and agricultural activities (Manojlović and Singh, 2012; Ninkov et al., 2012).

Consumers of the food products from organic and but also conventional agriculture in Serbia are more and more interested in their quality, particularly concentration of heavy metals and pesticides residues, which is very much dependent on the soil quality. In order to prevent soil contamination by TEs but also to increase essential TEs on soils where there is a need for that, it is important to analyze and monitor soil quality.

The aim of the research was to compare the impact of organic and conventional farming systems on soil quality with respect to trace elements (TEs) status.

2. Material and methods

A study was carried out on seven pilot farms located in Vojvodina, the northern part of Serbia. The province of Vojvodina is the most important agricultural region in Serbia, covering the Southeastern part of Pannonian Basin, with 88% of its total area being arable Vidojević & Manojlović (2007).The investigation was conducted at three representative farms certified for organic production (Stara Pazova, Kisač, Ljutovo) and four conventional farms (Rivica, Indjija, Kraljevci, Novi Slankamen) in total on 96 production fields with different history of farming practices.

Main soil chemical properties were analyzed by the following methods: the pH was measured in a 1:2.5 soil/water and soil/1MKCl suspension; the $CaCO_3$ content volumetrically using Scheibler calcimetar; the humus content by the Tjurin method; N total by CHNS analyzator Elementar; available phosphorus and potassium were extracted using the ammonium lactate solution (Egner and Riehm, 1960), and phosphorus was measured by spectrometer and potassium flame photometer.

Total and plant-available concentrations of TEs (DTPA) were determined in soil samples taken from 0-30 cm depth. The concentration of TEs was measured by atomic absorption spectrometer (AAS).

3. Results and discussion

3.1. Basic soil properties

The results showed high variability in soil fertility not only between the farming systems (organic/conventional), but also within the same production system - between different locations and even between plots on the same farm. Soil samples taken from conventional farms had lower pH values and lower humus contents compared to the samples from the organic farms (unpublished data).

Table 1: *Basic properties of soils from organic and conventional farms.*

Parameter	Min	Max	Average
pH [H_2O; 1:10]	7.0	8.67	8.2
pH [KCl; 1:10]	6.34	8.01	7.3
$CaCO_3$ [%]	1.68	24.0	8.9
Humus [%]	0.54	6.01	2.42
Total N [%]	0.03	0.3	0.12
P_2O_5 [mg 100^{-1}g]	3.08	188	24.7
K_2O [mg 100^{-1}g]	11.4	120	22.8

3.2. Essential trace elements

The total concentration of TEs in the soil indicates the potential of the soil to provide plants with microelements. Availability of TEs for plants depends on a number of factors, such as: pH-value land, $CaCO_3$ content, soil texture, and organic matter content.

In order to assess the provision of TEs to plants, concentration of plant-available TEs was determined after their extraction with DTPA solution (Fig. 1). The results show a variable concentration of essential TEs (Fe, Mn, Cu and Zn) in soil but the concentration of plant-available forms were adequate and above the lower limit of the optimal provision. Therefore, it is not expected that plants react positively to the fertilization with these elements. However, soil in Srem (Indjija, Rivica, Kraljevci, N.. Slankamen) is characterized by low concentration of available Fe (by an average of 7.4 mg kg^{-1}), which is insufficient for plant species that have increased needs for this element (fruit and grapes).

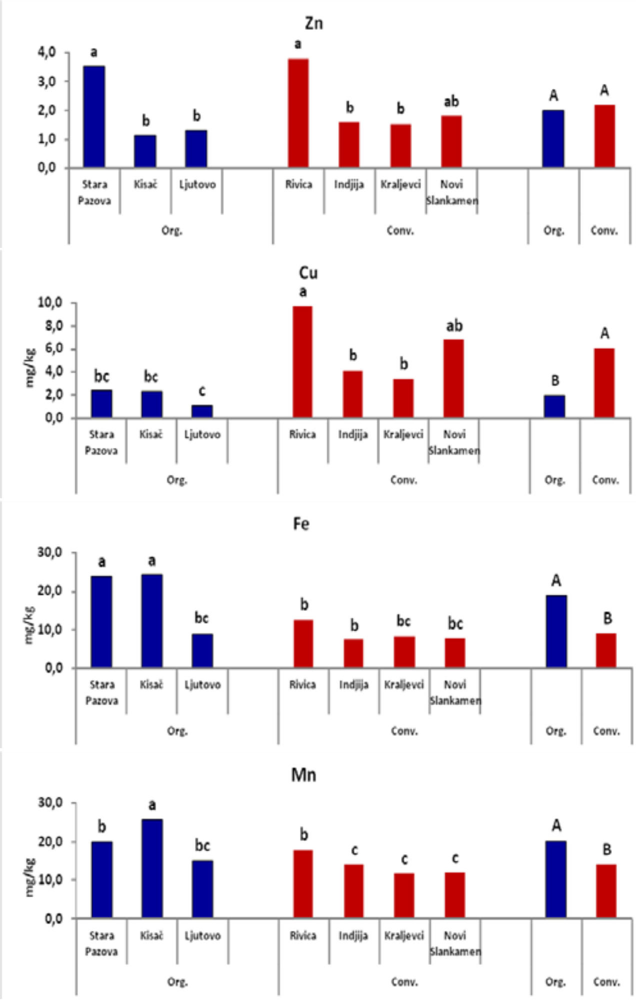


Fig. 1 *Concentration of essential plant-available TEs (Zn, Cu, Fe, Mn) in soils from organic and conventional farms.*

Some of the TEs, Cu, Zn, Mn, Fe, Mo, B, and Ni that are essential for plant growth, can become toxic to plants at high concentrations. Fig. 2 shows the total concentrations of Zn and Cu in investigated soils from organic and conventional farms.

According to Regulation on permitted amounts of hazardous and harmful substances in agricultural soil and methods for their testing (Off. Gazette of RS, no. 11/1990), maximum concentrations of Zn and Cu in soil are 300 and 100 mg kg^{-1}, respectively. Although, the limit for Cu in organic production is more strict (50 mg kg^{-1} of soil, according to Off. Gazette of RS, no. 51/2002), concentrations of Cu in all samples are just below the limit. Fig. 1 already showed low DTPA concentrations of Zn, Cu, Fe, Mn. In previous study of Popović et al. (2011) on soils in the vicinity of thermal power plants in Serbia, Bosnia and Croatia, the chemical speciation indicated that more than 99% of all investigated metals (Cd, Cu, Pb and Zn) in soil water extracts were complexed to fulvic acid. This is connected to relatively high soil pH (>6.5) and high contents of soil organic matter in these soils. Authors concluded that these soils have a large metal retaining capacity and high industrial activity had insignificant effect on soil quality with respect to bioavailability of TEs in these soils.

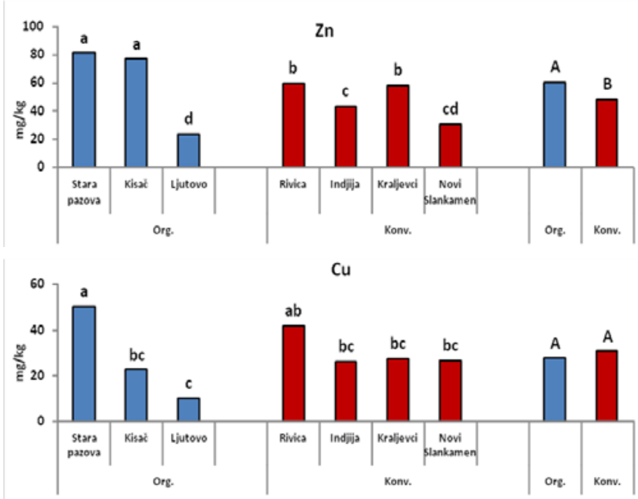


Fig. 2 *Total concentration of essential TEs (Zn, Cu) in soils from organic and conventional farms.*

3.3. Toxic trace elements

Mean values for the total concentration of toxic TEs in the soil taken from the tested farms are shown in Figs. 3 and 4. The total concentration of all analyzed toxic TEs in the soil, except for Ni, was lower than the maximum permissible content of the Regulation on permitted amounts of hazardous and harmful substances in agricultural soil and methods for their testing (Off. Gazette of RS, no. 11/1990). The total concentration of Ni in few individual plots were above maximum permissible levels prescribed by law (50 mg kg^{-1}) and were most likely natural geochemical origin, according to review Manojlović and Singh (2012).

Since the solubility and availability of TEs for plants depends on a number of factors in soil, such as: pH-value, $CaCO_3$ content, soil texture, organic matter content, in order to estimates of the potential entry of these toxic elements into the food chain (soil-plant) plant-available concentration of heavy metals was determined after their extraction with DTPA. Plant-available concentration of investigated TEs (Cd, Pb, Ni, Cr) are very low (not shown) and does not present a threat to the food chain.

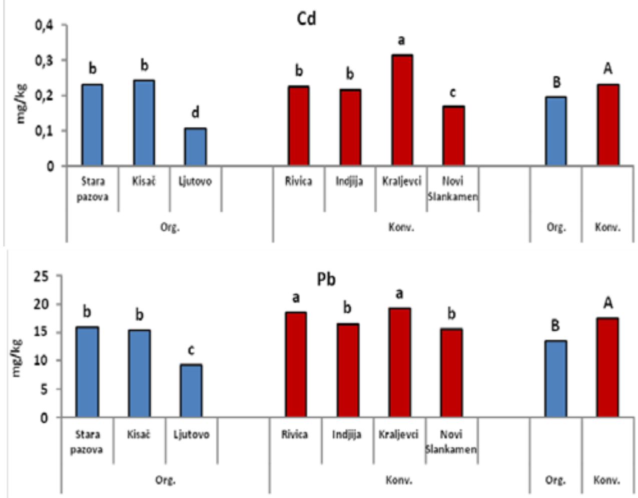


Fig. 3 *Total concentration of toxic TEs (Cd and Pb) in soils from organic and conventional farms.*

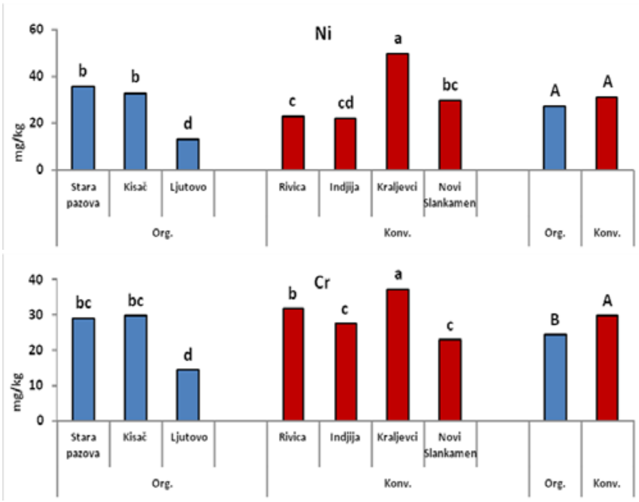


Fig. 4 *Total concentration of toxic TEs (Ni,and Cr) in soils from organic and conventional farms.*

4. Conclusion

The results have shown that total TEs concentrations in soils are under maximum allowance values and therefore risk of TEs contamination is low. However, low level of plant available TEs, particularly zinc (Zn), are found on the most of the investigated plots.

The concentrations of available microelements (Fe, Mn, Cu and Zn) in all soil samples were above the lower limit of optimal provision and field crops and will not positively react to the fertilization with these elements. Soils in Srem are characterized by a low concentration of available Fe which is insufficient for the crops that have increased needs for this element (fruit and grapes).

Regulations on permitted amounts of hazardous and harmful substances in soil and methods for their examination in 1990 (Gazette of RS, no. 11/1990) defines the maximum allowable values for heavy metals in soil. The total content of all analyzed heavy metals in the soil, except Ni, was lower than the maximum content specified in the Regulation. The total content of Ni in certain plots in Srem is above the maximum permitted level prescribed by law (50 mg kg-1) and probably is the natural geochemical origin, as demonstrated by previous research.

Total concentrations of Pb, Cr and Cd were significantly higher in soils from farms with conventional agricultural production compared to soils from farms with organic production.

4. References

1. Manojlović, M**,** R. Čabilovski. Soil fertility as a base for organic farming in Vojvodina. In: Proceedings of 22[nd] International symposium “Safe food production”, 19-25 June 2011, Bosnia and Herzegovina, Trebinje. p. 237-240.

2. Manojlović, M, R. Čabilovski, M. Kalentić. Soil fertility: Organic vs. Concentional farming Systems in Vojvodina, northern Serbia. In: Proceedings of International Conference on Organic Agriculture and AGRO-ECO TOURISM in the Mediterranean, 16-18 September 2011, Zakynthos, Geece. p. 26-27.

3. Manojlović, M, B.R. Singh. Trace elements in soils and food chains of the Balkan region. Acta Agriculturae Scandinavica, Section B - Plant Soil Science 62, 2012 (8), 673-695.

4. Ninkov, J, Đ. Paprić, P. Sekulić, T. Zeremski-Škorić, S. Milić, J. Vasin, I. Kurjački. Copper content of vineyard soils at Sremski Karlovci (Vojvodina Province, Serbia) as affected by the use of copper-based fungicides. INT J ENVIRON AN CH 92, 2012 (5), 592-600.

5. Off. Gazette of RS, no. 11/1990. Regulation on permitted amounts of hazardous and harmful substances in agricultural soil and methods for their testing.

6. Off. Gazette of RS, no. 51/2002. Regulation on methods of organic plant production and production and on collecting forest fruits and curative plants as products of organic agriculture.

7. Popovic, O, Å.R. Almås, M. Manojlovic, S. Muratović, B.R. Singh. Chemical speciation and bioavailability of Cd, Cu, Pb and Zn in Western Balkan soils. Acta Agriculturae Scandinavica, Section B - Plant Soil Science 61, 2011 (8), 1651-1913.

8. Čuvardić, M, P. Sekulic, Ž. Mihaljev, M. Zivkov-Balos, Ž. Čupić. Essential and toxic elements in soils, feed and food in Vojvodina Province. In: M. Szilagyi and K. Szentmihalyi (eds.) Proceedings of the International Symposium on Trace Elements in the Food Chain, 2006, Budapest, Hungary, p. 22-224.

9. Vidojević, D, M. Manojlović. "Overview of the soil information and policies in Serbia". In: "Status and prospect of soil information in South-Eastern Europe: soil databases, projects and applications". T. Hengl et al. (eds) Office for Official Publications of the European Communities, EUR 22646 EN, Scientific and Technical Research series ISSN 1018-5593, 87-98 (2007).

USE OF SOPHISTICATED LYSIMETER TYPES TO MEASURE SOIL WATER BALANCE PARAMETERS WITH HIGH ACCURACY

Prof. Dr. Ralph Meissner[1], Dr. Holger Rupp[1], Dr. Manfred Seyfarth², Dr. Michael Gebel³
[1]Helmholtz Centre for Environmental Research - UFZ, Germany, ² UGT-Environmental Measurement Devices Ltd., Germany, ³ Society for Applied Landscape Research (GALF) bR, Germany
E-mail: ralph.meissner@ufz.de, holger.rupp@ufz.de, manfred.seyfarth@ugt-online.de, gebel@galf-dresden.de

Abstract *Intensive cultivation has resulted in an accumulation of nutrients and hazardous substances in the soil. These solutes represent a potential risk to the quality of both surface and groundwater. It is of vital interest to know the quantity and quality of seepage water which leaves the root zone, then enters the aquifer and finally the surface water system. To solve the problem we carried out trials at different scales to get information on how different land management methods influence the amount and quality of seepage water. We used direct lysimetry methods for measuring water and solute fluxes in soils. The combination of lysimeter studies with field experiments at different scales opens new possibilities for modelling and management of watersheds. The paper informs about advances in lysimeter techniques and technology and gives a practical application of this technique to measure the amount of dew. Based on an example the combination of lysimeter measuring results with the WebGIS based model STOFFBILANZ for calculating nutrient balances at catchment scale will be shown.*

KEYWORDS*: LYSIMETER, MEASURING TECHNIQUE, SOIL WATER REGIME, WATER FLUX, SOIL MOISTURE, ACTUAL EVAPOTRANSPIRATION, UP-SCALING, WATER AND SOLUTE MODELLING*

1. Introduction

In the international literature the term “lysimeter” is used for different measuring devices. According to our understanding it belongs to the direct methods to measure water and solute fluxes in soil. The German Industrial Standard DIN 4049-3 defines a lysimeter as a device to collect drainage water for mass and solute balances in relation to soil, parent rock, vegetation, local climate and other site conditions. In general, it consists of a square or round vessel filled with soil and a mechanism to collect and quantify the amount of water leaving it at the bottom. Only lysimeters permit a direct determination of the water amount percolating through a soil profile and of the type and amount of solutes contained in it. Hence, they allow a much more reliable calculation of solute loads carried towards the groundwater than any other method [1]. If the lysimeter is weighable, actual evapotranspiration can be calculated from its weight (mass) change.

A wide range of lysimeters have been developed and used in the past, ranging from small, free-draining pan lysimeters or tension-controlled lysimeters that often only capture a small portion of the drainage water, to large drainage lysimeters that limit divergence and capture most or all of the drainage water within a prescribed area. The main difference between the used lysimeter types are:

- soil filling procedure (disturbed – undisturbed)
- weighability (weighable or non-weighable)
- lysimeter size (depends on scientific question and scale of observation)
- lower boundary conditions (free drainage or suction controlled drainage)

The design of a lysimeter (required surface and length) depends mainly on scientific question, manner of vessel filling (disturbed or undisturbed), lower boundary, and location of installation. Small scale heterogeneity of a site will be averaged using a larger lysimeter base area. Furthermore, lysimeters with vegetation should represent natural crop inventory and maximal root penetration depth should be taken into account. Except the generation of well-defined recurrences of the same soil conditions it is recommended to fill the lysimeter vessel monolithically. According to our knowledge a large weighable lysimeter is the best method for obtaining reliable data about seepage water quantity and quality. However, the construction and maintenance of large drainage lysimeters (especially the weighing type) is expensive. To solve these problems new lysimeter techniques have been developed and used in different countries [2].

The objectives of this paper are i) to inform about advances in lysimeter techniques and technology, ii) to demonstrate its use for measuring of soil water balance parameters (for example dew) and iii) to give an example for the combination of lysimeter measuring results with the WebGIS based model STOFFBILANZ for calculating nutrient balances at catchment scale.

2. Material and methods

An optimal soil-monolith extraction with minimal disturbance during the filling procedure of the lysimeter vessel is of critical importance for establishing flow and transport conditions comparable to natural field conditions. In the past, several methods were used to extract and fill lysimeter vessels vertically - including hand digging, employing sets of trihedral scaffolds with lifting blocks and ballast, or using heavy duty excavators, which could shear and cut large blocks of soil. More recently, technologies have been developed to extract cylindrical soil monoliths by using ramming equipment or screw presses. One of the great disadvantages of the mentioned methods is the compaction or settling of soil that occurs during the “hammering” or “pushing”.

For this reason a new technology was developed, which cuts the outline of the soil monolith employing a rotary cutting system [3]. The principal scheme of this technology is shown in Figure 1. The newly developed cutting tool makes it possible to cut out soil monoliths with high precision. The soil monolith is not damaged during the cutting process and the extraction site is only minimally affected. A tripod frame is used to bring the lysimeter vessel into a vertical position and hold it vertical during cutting. The vessel is made of stainless steel and can be coated on the inside with an inert protective surface. At the top of the frame there is a hydraulic cylinder, which in conjunction with guard and adjustable slip rails guides the lysimeter vessel during the cutting process. At the bottom of the vessel there is a rotary cutting tool. It is driven by a small hydraulic motor, also located at the bottom of the vessel, using a chain and sprocket arrangement. The cutting tool can be fitted with various types of chisels to adjust it to soil and site conditions.

While rotating, the cutting tool carves out the soil some 4 cm wider than the diameter of the lysimeter vessel, i.e. it leaves an excess of 2 cm of soil all around the rim of the vessel. With its own mass as the driving force, the vessel concurrently penetrates into the carved soil and shears off the aforementioned excess in the process. If necessary, an additional force can be applied by the hydraulic cylinder on top of the frame. Because the vessel slides over a soil core, which is slightly larger than itself, a tight fit between soil and vessel results. This precludes gaps, which may act as preferential flow paths.

On one side of the vessel a pit needs to be dug, which is 20 cm wider and 40 cm longer than the diameter of the lysimeter vessel, and some 10 cm deeper than the vessel will eventually penetrate into the soil. This is necessary to accommodate the metal plate and the accompanying hydraulic pushing device for cutting the base of the monolith. Furthermore, the peelings from the cutting process are discarded into the pit, though a much smaller size would be sufficient for that. After the desired depth is reached, the cutting tool stops rotating and the chisels are detached. Next, the monolith is severed at the bottom and the cutting plate left attached to the bottom of the vessel. Then a crane is employed to lift the whole assembly out of the pit. Smaller monoliths (e.g. surface area < 0.5 m² and depth < 1.0 m) can be lifted by aforementioned hydraulic cylinder, without any additional lifting device. Once on the soil surface, the rotary cutting tool and the hydraulic motor, which drives it, are removed. After a lid has been fixed on top of the vessel, it is turned upside down. Now the lower 15 cm of soil in the monolith are removed and replaced with a graded filter layer made of quartz sand and gravel (0.1 - 0.5 mm, 0.71 - 1.25 mm and 3.15 - 5.6 mm in diameter). The time required to collect a soil monolith depends on soil, site conditions and size of the soil column. Usually it takes one day for the whole procedure to obtain a large undisturbed soil monolith. This technology has been used successfully for different soil types (from gravel to sand to clay) and for different lysimeter sizes (surface area 0.03 – 2 m^2 and depth until 3 m). Different types of cutting tools are available to cut out the soil monoliths; the most important tools are displayed in Figure 2. Until now more than 400 monoliths (from sand to gravel to clay) have been extracted with this method. Preferential flow did not occur in any of them.

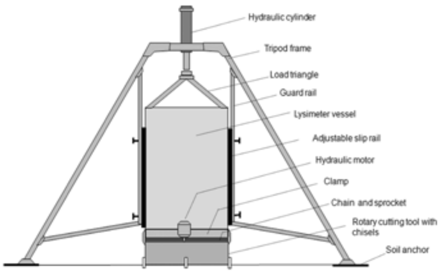


Fig. 1 *Sketch of the device for the vertical collection of a lysimeter vessel with an undisturbed soil monolith*

Lysimeters are usually located in a special lysimeter station with an access for functional inspection as well as for the accommodation of measurement, control and weighing devices. In most cases such a station involves an expensive steel or concrete cellar. To reduce cost and secure mobility a containerised polyethylene (PE-HD) lysimeter station was developed. The principle scheme of PE-HD lysimeter station, where four lysimeter vessels are located in a clover type arrangement around a central access is shown in Fig. 2. Variations of the amount and arrangement of lysimeter vessels are possible and demonstrated in [3]. The containerisation allows the establishment of lysimeters at virtually any location, e.g. directly at the extraction site.

There are different newly developed lysimeter types available. Figure 3 shows a schematic of a weighable gravitation lysimeter equipped to measure water and solute flux and to calculate actual evapotranspiration. This type of lysimeter can be produced with surface areas from 0.5 to 2.0 m^2 and total depths of 1.0 to 3.0 m; in Germany the lysimeter type with the size of 1.0 m² surface area and a total depth of 2.0 m is often used. The lysimeter vessel was extracted out of the investigation site as an undisturbed soil monolith with the collection technology described before. As described above, a 15 cm thick filter layer (sand over coarse sand over gravel) was placed at the lysimeter bottom to minimize natural flux disturbances.

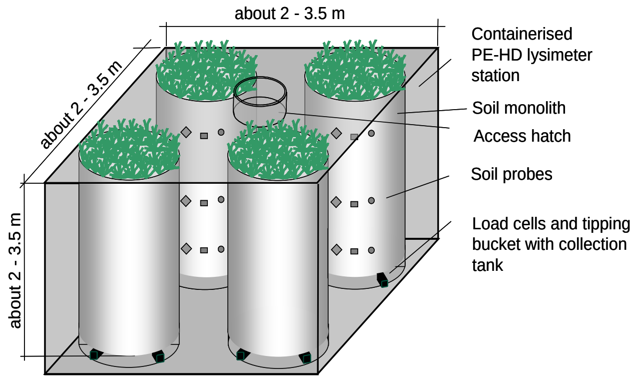


Fig. 2 *Sketch of a containerized polyethylene (PE-HD) lysimeter station with four lysimeters in a clover arrangement and an access hatch at the centre*

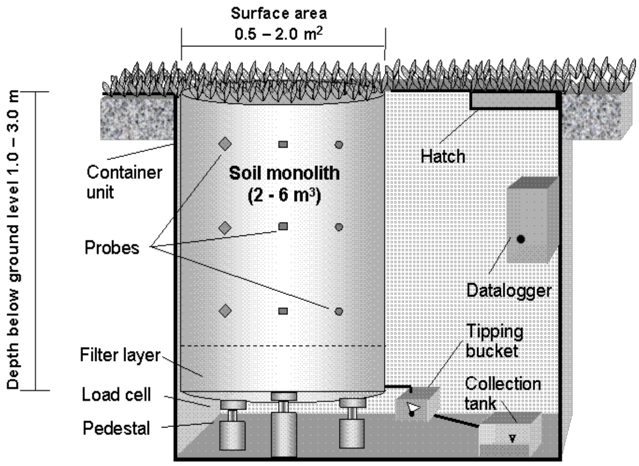


Fig. 3 *Sketch of a weighable gravitation lysimeter*

Instead of a mechanical weighing system, our lysimeters are equipped with three shear stress cells, which are placed on top of aluminium pedestals. Even at a total lysimeter mass of 4.000 to 4.500 kg this weighing system can register mass changes of ± 20 g [4]. Tensiometers, TDR (time-domain reflectrometry) probes, thermometers and suction cups are installed at depths of 0.30 m, 0.90 m and 1.50 m. Measured values are consolidated and stored in a data-logger, whose recording interval is chosen by the user. It permits a very high temporal resolution (< 1 minute). The amount of seepage water is measured with a tipping bucket (values are stored by data logger) and collected in a storage container from which water samples can be taken for chemical analysis. The tube leading from lysimeter bottom to the tipping bucket has a large diameter and is open to the atmosphere to allow free drainage out of the lysimeter. There is no hanging water column. On overview regarding further newly developed lysimeter types as a weighable groundwater lysimeter or a large fen lysimeter is described in [3] and [5].

3. Results and discussion

3.1 Measuring the amount of dew

In water balance studies, lysimeters are typically used to quantify rainfall, actual evapotranspiration and drainage. However, if the weighing precision is high enough as in case of the lysimeters introduced here, precipitation in the form of dew, fog and rime can be measured accurately [4].

As an example of the high precision of the new weighing technique Figure 4 shows the chart of the lysimeter mass (the mass change allows to calculate the change in the amount of water stored in the soil column) recorded at northern Germany over a 5-day-period in April. No rainfall occurred during April 16 until the evening of April 18 so that the lysimeter mass decreased due to evapotranspiration. In the early morning of April 17 dew formation is visible because the mass of the lysimeter increased slightly. The rising sun's radiation leads to increasing evapotranspiration with a typical day-night rhythm. In the late evening of April 18 a rain event occurs, which led to an increased mass change of the lysimeter. Nine further rain events with different amounts of precipitation were registered until the afternoon of April 19. Altogether 5.5 mm of precipitation were measured, leading to an increased mass of 5.5 kg. Furthermore, the installed computer software allowed the presentation of all measured parameters in detail (for example average, minimum and maximum values of the measured data). The measuring process is individually adjustable (depending on the problem in question) and allows a highly sophisticated spatial and temporal resolution.

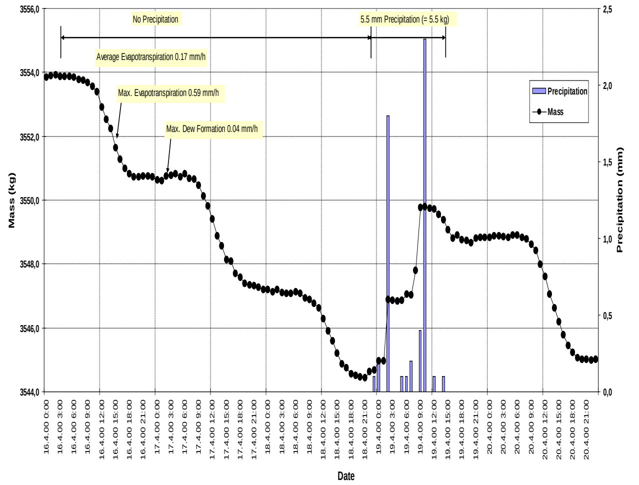


***Fig. 4** Example of the diurnal mass change of a weighing gravitation lysimeter planted with grass*

3.2 Combination of lysimeter measuring results with modelling

Based on an example from a research project in China the combination between lysimeter – field and sub-catchment measurements with the WebGIS based model STOFFBILANZ for calculating nutrient balances at the total catchment scale will be shown [6]. The software STOFFBILANZ [7] was used to calculate runoff, soil loss, sediment and nutrient input into the Sheyuchuan experimental sub-catchment (about 28 km^2) as well as in the entire Miyun catchment area (about 15,600 km^2). The approach requires a minimum of parameters to run the model and is suitable for modelling at the meso-scale. To guarantee a sufficient temporal resolution of the simulation in the monsoon influenced region, the following procedures were carried out on a daily basis:

- calculation of the FAO dual crop evapotranspiration undersoil water stress conditions
- direct runoff calculation according to the Curve Number Approach
- estimation of erosion yield according to the USLE-M approach
- sediment input into surface water according to [7]

Particulate P inputs into surface waters were calculated considering sediment input, nutrient enrichment and total P (TP) content in topsoil, which was derived from land use type and soil texture. In addition, we simulated diffuse dissolved P losses with the help of estimated P export coefficients for seepage water and direct runoff. The simulation of N surplus in the root zone, N input via direct runoff and N input via deep percolation is based on mass balances calculated for each grid cell [7].

Calibration and testing of the modelling approach STOFFBILANZ was done on the basis of the continual monitoring at the lysimeter station and at a gauge measuring station at the end of the small sub-catchment Sheyuchuan as part of the total Miyun reservoir. The lysimeter data revealed a substantial amount of seepage water in July 2011, caused by a heavy rainfall of more than 100 mm/d (Fig. 5). The monitoring results underline that the episodic character of the rainfall pattern and the processes which this sets into motion have to be modeled with high resolution at the meso-scale in order to properly depict critical source areas, transport pathways and solute loads. The lysimeter as well as field and sub-catchment observations were used to learn from the processes of runoff generation and to calibrate the crop evapotranspiration under soil water stress conditions (ETcadj) and deep percolation simulation. Figure 5 depicts the result of this calibration. The simulation of evapotranspiration corresponds well with the observation. In summertime the amplitude of simulated evapotranspiration is much lower than the one observed by the lysimeter. This is due to the fact that the simulated soil moisture as well as the evapotranspiration term remains at a constantly high (maximum) level during that period. Plant interception and the evaporation from the plant surface are not included in the modelling in an adequate way, because it is focusing on soil-water-plant-interactions. In contrast to that the lysimeters give continual (every 10 min) information about the changes of mass, caused by the fluctuating evapotranspiration term. A positive peak appears after the rainfall event and shows, how much water is evaporated from the wetted soil, but also from the wetted plant surface. The observed evapotranspiration by the lysimeter is therefore a little bit higher compared to the simulated one.

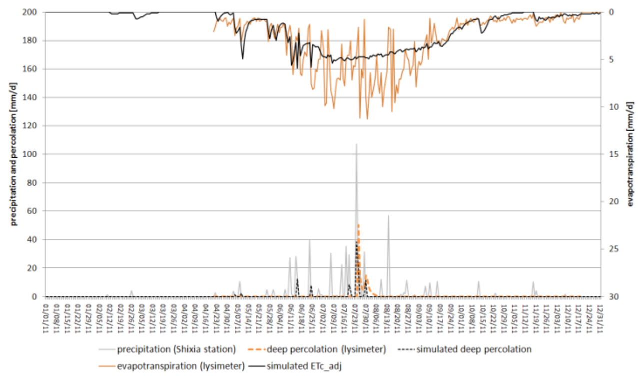


***Fig. 5** Comparison of measured lysimeter data and model results with STOFFBILANZ for actual evapotranspiration and deep percolation for 2011*

The simulated values were compared to the observed ones for average values of periods of 7 days. The calculated Nash–Sutcliffe model efficiency coefficient is 0.78. According to the soil-water-fluxes, which are more important from our point of view, the results of the simulated deep percolation correspond well with the observed one with a calculated Nash–Sutcliffe model efficiency coefficient of 0.75 for the 7 day periods. A daily comparison was neglected, because flow distance and retention time is neither included in the soil-water-budget of the ETcadj approach nor in the curve number approach.

After successful calibration with lysimeter results, the knowledge of local process generation was transferred to the total catchment area of Miyun. According to the meteorological data set all calculations are based on the climate data pool of 1960–1990, combined with the event-based daily meteorological data for the year 2009 from the central Shixia meteorological station in the Miyun catchment area. The results of the FAO-grass reference evapotranspiration modelling range from 970 mm/a in the South-Eastern part to 1.293 mm/a in the North-Western part. The average value of direct runoff for the total catchment area is about 11.7 mm/a. Percolation from the evaporating layer into the root zone was calculated by the ETcadj approach with an average value of 132.5 mm/a for the total catchment. Percolation from the root zone into groundwater is about 3.1 mm/a (Fig. 6).

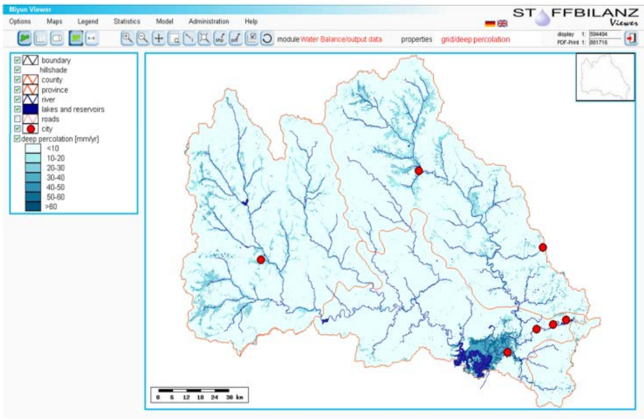


Fig.6 *Simulation of deep percolation (groundwater recharge) in the Miyun catchment area (reference year 2009)*

According to information from our Chinese partner, the Beijing Water Authority, the annual water inflow into the Miyun reservoir is about 200,000,000 m^3, corresponding to a total runoff of 13 mm/a. These results correspond to runoff values from comparable rivers in the catchment (e.g. Bai river, 17.3 mm/a or Chao river, 15.4 mm/a). Water abstractions, which can be estimated to be at least 20 % of the total runoff, have to be added to compare the observed values with the simulated total runoff in the Miyun basin of 15 mm/a. According to these estimations the simulation results are in good agreement with the range of the literature and monitoring data.

The estimation of nitrogen (N) surplus was realized by a very soft balancing approach due to the lack of more precise data to agricultural management and waste water treatment in the region. Average values of N input into surface waters via direct runoff and deep percolation are about 2.7 kg N/ha and 2.2 kg N/ha, respectively (Fig. 7). Nitrate concentrations in leachate (deep percolation) were calculated with app. 409 mg/l on temporary cropland of the dry bottom of the Miyun reservoir. These values are well in the range of the first observed seepage nitrate concentrations of the lysimeter (average of 398 mg/l). Diffuse N input into surface waters from all land use types was approximately 7,833 t/year in total (4,217 t/year by direct runoff; 3,616 t/year by deep percolation).

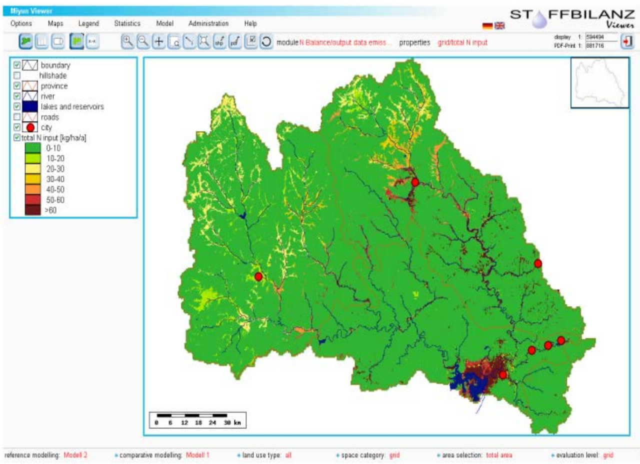


Fig. 7 *Simulation of the total diffuse N input in the Miyun catchment area with the model STOFFBILANZ (reference year 2009)*

5. Conclusions

There is an international tendency towards a wider use of direct drainage lysimetry methods for measuring water and solute fluxes in the soil. This technique ensures reliable drainage data, but requires relatively large investment and maintenance costs. Progress is visible in the technological development of newly lysimeter types with a high precision weighing technique. More efforts are necessary to reduce the costs for the application of the lysimeter technique.

Lysimeter investigations will be an essential tool for scaling up results achieved in small-scale experiments to larger geographical units. Combination of lysimeter studies with direct measurements in the field or catchment and in combination with modelling approaches allow scenario simulation of topical climatic and hydrologic questions (e.g. climate change, different land management, groundwater recharge etc.).

The presented work based on research projects which were funded from the Federal Ministry of Research and Education of Germany (BMBF); especially KULUNDA-project- FK 01LL0905D and MIYUN-project- FK 02WM1047. Responsibility for the contents of the paper rests upon the authors.

6. References

[1] Weihermueller, L., Siemens, J., Deurer, M., Knoblauch, S., Rupp, H., Goettlein, A., Puetz, T. In situ soil water extraction: a review. Journal of Environmental Quality. 36.2007. pp. 1735-1748.

[2] Balykin, D.N., Puzanov, A.W., Stephan, E., Meissner, R. Using the innovative lysimeter technology in the German–Russian research project "KULUNDA". In: Mueller, L., Sheudshen, A.K., Eulenstein, F. (eds.), Novel methods for monitoring and managing land and water resources in Siberia. Heidelberg, Springer Water, 2016. pp. 515-539.

[3] Meissner, R., Rupp, H., Seyfarth, M. Advanced technologies in lysimetry. In: Mueller, L., Saparov, A., Lischeid, G. (eds.), Novel measurement and assessment tools for monitoring and management of land and water resources in agricultural landscapes of Central Asia. Heidelberg, Springer Cham, 2014. pp. 159 – 173.

[4] Xiao, H., Meissner, R., Seeger, J., Rupp, H., Borg, H. Testing the precision of a weighable gravitation lysimeter. Journal of Plant Nutrition and Soil Science. 2009. 172. pp. 194-200.

[5] Rupp. H., Meissner, R., Leinweber, P., Lennartz, B., Seyfarth. M. Design and operability of a large weighable fen lysimeter. Journal of Water, Air, and Soil Pollution. 2007. 186. pp. 323 - 335.

[6] Meissner, R., Gebel, M., Hagenau, J., Halbfass, S., Engelke, P., Giessler, M., Duan, S., Lu, B., Wang, X. WebGIS-based approach to simulate water and solute fluxes in the Miyun basin in China. In: Borchardt, D., Bogardi, J., Ibisch, R. (eds.), Integrated Water Resources Management: Concept, Research and Implementation. Heidelberg, Springer Cham. 2016. pp. 515-539.

[7] Gebel, M., Uhlig, M., Halbfass, S., Meissner, R., Duan, S. Predicting erosion and sediment yield in a mesoscale basin in the semiarid monsoon region Miyun/China. Ecological Processes. 3:5. 2014. pp. 1-11.

IRRIGATION WATER EFFICIENCY ON IRRIGATION SYSTEMS OF KAZAKHSTAN

Researcher Grigoriy Rau
Kazakh National Agrarian University – Almaty, Kazakhstan

Abstract: *Irrigated agriculture is the largest water consuming industry in agricultural sector of Kazakhstan consuming up to 70% of the total water resources consumed by all sectors of the economy. One of the methods for increasing the irrigation water efficiency is the construction of technically advanced irrigation systems, allowing use of water-saving irrigation technology: drip irrigation, enabling to save irrigation water by 20-30% and increase the productivity by 2.0-2.7 times.*

KEYWORDS: IRRIGATION, PRODUCTIVITY, EQUIPMENT, HARVEST, IRRIGATION RATE, SPECIFIC WATER CONSUMPTION

1. Introduction

Irrigation in Kazakhstan is an objective necessity in transforming natural systems, conversion of deserts and semi-deserts in highly productive agricultural lands, irrigation is designed to make a significant contribution to the agri-food program of the country and social and economic wellbeing.[1] Irrigated agriculture, which occupies 2 335 thousand hectares or 7% of the total sown area of agricultural production in the country, in case of optimal land and water resources use it could become a reliable sector of agricultural production and provide up to 30% of total crops production. Strategically important for Kazakhstan products such as cotton, rice, sugar beet, tobacco, vines, melons are grown only on irrigated lands. Irrigated agriculture is the largest water consuming industry in agricultural sector of Kazakhstan consuming up to 70% of the total water resources consumed by all sectors of the economy. High water-intensive irrigation in agriculture is caused by the lack of standardization and regulation of the water supply to the irrigation system, non-compliance with irrigation regime and optimal irrigation rates.

2. Methods and study results

Collection and processing of irrigation systems data is conducted from industrial organizations and farms to measure water use when cropping. Experimental studies on crops irrigated lands in southern Kazakhstan.

The demand for water is not the same for a variety of crops. If the irrigation rate for wheat in the South Kazakhstan is in the range of 800-1600 m^3/ha, for maize is 3000-4000 m^3/ha, for sugar beet and perennial grasses irrigation rate reaches 5000-6000 m^3/ha.

Irrigation water efficiency in cultivation of crops on irrigated lands is a function of irrigation rate and yield. The higher yields and lower irrigation rate mean higher irrigation water efficiency. In the Northern Kazakhstan for spring wheat cultivation with yield of 1.5-2.0 t/ha water demand is 2-3 times lower than in the semi-desert areas of the Kyzylorda and South Kazakhstan regions, in spite of the possibility of obtaining higher yields of spring wheat up to 2.5 t/ha.

Analysis of irrigation water efficiency on irrigated lands shows that the highest productivity is observed in the cultivation of vineyards 1.0-1.30 US dollars per 1 m^3 of water consumed, while cotton 0.22-0.26 US dollars per 1 m^3 of water consumed. Multiannual average of actual data on the volume of water (gross) consumption per 1 tonne of produce and the irrigation water efficiency in the cultivation of crops on the irrigated lands of Kazakhstan is presented in Table 1.

Table 1. Specific water consumption by crops and irrigation water efficiency on irrigation systems.

Agricultural crops	Specific water consumption, m^3/t	Irrigation water efficiency, US dollars per 1 m^3 of water
Rice	7500-9000	0.06-0.08
Cotton	5500-7000	0.22-0.26
Corn for grain	1500-2000	0.10-0.14
Sugar beet	600-800	0.25-0.28
Cereal	1400-1700	0.11-0.16
Vegetables	500-700	0.24-0.27
Melons	180-260	0.19-0.21
Orchards and vineyards	800-900	1.0-1.3
Perennial herbs	2500-3000	0.07-0.09

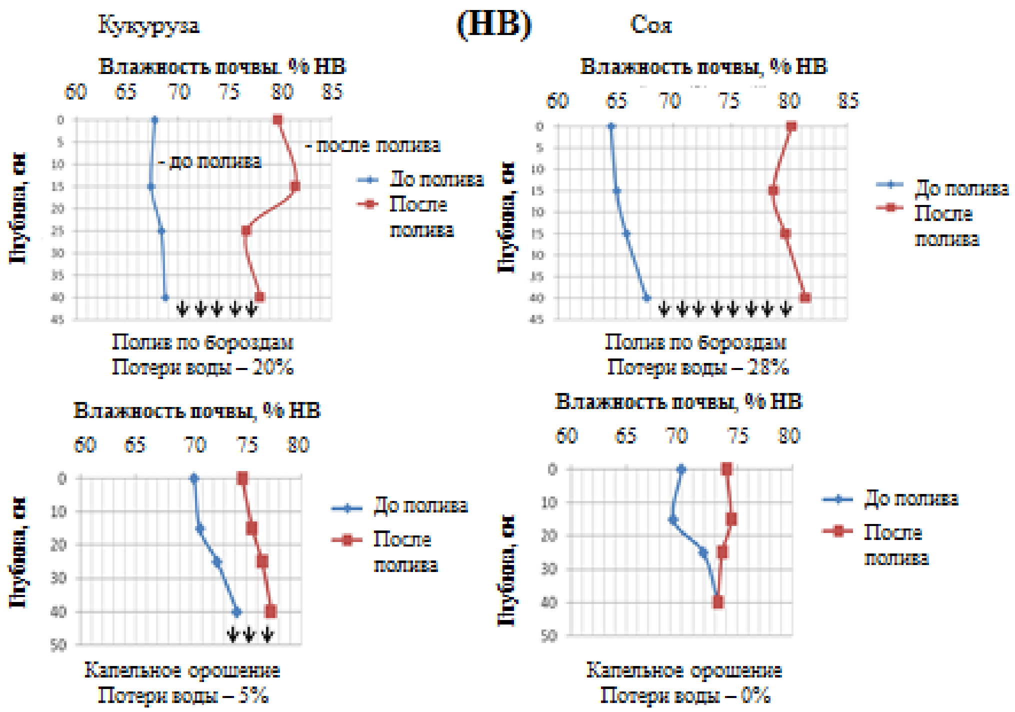
Irrigation water efficiency depends on the irrigation technique and technology. When drip irrigation technology employed water consumption per ton of produce is lower and crop yields higher. [2]

During experiments on irrigated lands of Talgar district, Almaty region, maize under drip irrigation water technology the irrigation rate is 250-200 m^3/ha, over the irrigation period - 4300 m^3/ha, for soybeans 240-180 m^3/ha and 3600 m^3/ha, respectively (Table 2). In case of furrow irrigation the water consumption rate for corn is 1200 m^3/ha, irrigation rate - 9900 m^3/ha, for soybean 8500 m^3/ha and 6400 m^3/ha, respectively. The soil moisture varied with furrow irrigation over the period from 60% HB to 83% HB (Figure). Water losses during irrigation constituted 20-28%. Drip irrigation compared with surface irrigation allows to maintain optimum soil moisture in the range of 70-80% HB and increase crop yields by 2.5 times. Irrigation water efficiency under drip irrigation for soybean 7 times, maize 4 times higher than under furrow irrigation.

Table 2 **-** *Irrigation water efficiency when watering corn and soybeans with furrow and drip irrigation*

Farm	Agricultural crops	Irrigation norm, m^3/ha	Irrigated area, ha	Yields, t/ha	Gross output, t	The volume of water consumed, thousand m^3	Irrigation water consumed per unit of agricultural produce, m^3/t	Irrigation water efficiency, tons / thousand. m^3
Irrigation ditch, furrow irrigation								
LLP Kyzylzharyn	Soybean	6150	246	2.90	713.4	2568,9	360.1	2.78
Farm Baitkai	Corn	9800	3	4.12	12.36	47,429	383.6	2.61
Farm Badenko	Corn	5350	22	4.12	90.64	189,84	209.4	4.77
Drip irrigation								
LLP Kyzylzharyn	Soybean	3600	246	7.25	1783.5	88,56	49.7	20.1
Farm Baitkai	Corn	4300	3	8.24	24.72	1,29	52.2	19.2
Farm Badenko	Corn	4300	22	8.24	181.28	94,6	52.2	19.2

Soil moisture in percent of field capacity



Drip irrigation system in the Sairam district of South Kazakhstan region is installed on an area of 160 hectares. Water intake from Aksu river flow to the sump with dimensions 30m * 120m = 3600m^2.

From the sump water is supplied by two 4AMN31S brand pumps in discharge pipes. The total length of the discharge pipes are 8.0 km including 300 mm diameter pipes 4.5 km; 270 mm diameter pipes 3.5 km. On the route of the main pipeline five containers are mounted with gravity filter system. Each container irrigates a land block with an area of 32 hectares. In one land block are 4 fields, each with an area of 8 hectares. To each container penstock is connected (steel pipe with diameter of 125mm), which has a regulating valve. The pipeline of 200 m length reaches the center of the block, where 4 valves are placed with 80 mm in diameter, from which water is supplied to the temporary sprinklers (fire) hoses with a diameter of 80 mm, a total length of 1600 m, i.e. each field of 200 x 400 m size has 2 threads with length of 400 m made of fire hoses. From the fire hoses set out droppers with holes (plastic tubes with a diameter of 10 mm), length 400 m in both directions.

On each field 242 droppers are placed. The total length of the droppers on a field of 8 ha is 48.4 km or per hectare of irrigated land accounts: 48.4 km/8 ha = 6 km of polyethylene pipes. On 160 hectares of irrigated land 960 km of polyethylene pipes are laid.

Watering of tomatoes is done in blocks, i.e. from each container, water is supplied for 5 blocks, then from each of the valve (4 pcs) one field is watered. Each field is watered for 6 hours. Each block is watered within 1 day, i.e. 6 hours * 4 fields = 24 hours. Every 3 hours washing of filters is performed in the container for 60 seconds. The irrigation technology is shown in the diagram of drip irrigation.

Tillage and fertilization: plowing - April; planting seedlings - tomato - May; cultivation - after planting; weeding by hand, during the growing season 2 times; inter-row cultivation of soil - manually.

Irrigation plot is divided into 2 types of row spacing:

1-row spacing of 1.90 m.

2-row spacing of 1.45 m.

Average row spacing 1.68 m.

Chemical treatments from pests and Boleyn were performed every 9 days. Mineral fertilizers were applied via irrigation water in the amount of 750 kg/ha of potash; 750 kg/ha of superphosphate and 1 t/ha of ammonium nitrate. Pesticides were not used.

Experimental studies have shown that drip irrigation system is effective compared with furrow irrigation, the amount of water during the growing season in the area of drip irrigation in the Sairam district is:

- with the surface irrigation (furrow) 4500 m^3/ha * 160 = 720.0 m^3

-with drip irrigation 756 m^3/ha * 160 = 120.96 m^3

Irrigation water economy in drip irrigation case is: 720.0-120.96 = 559.04 m^3 or 83.2% and the efficiency of irrigation water use is 2.7 times higher than with furrow irrigation.

3. Conclusion

Irrigation water efficiency of irrigation systems of Kazakhstan depends on many factors, in particular the structure of sown crops, land use intensity, and used technology. One of the methods for increasing the irrigation water efficiency is the construction of technically advanced irrigation systems, allowing use of water-saving irrigation technology: drip irrigation, enabling to save irrigation water by 20-30% and increase the productivity by 2.0-2.7 times.

4. References:

1. Концепция перехода Республики Казахстан к устойчивому развитию на 2007-2024 гг.-Астана, 2007.-69с.
2. [Электронный курс]: Передовые методы орошения – статья Израиль: web http//alecon.co.il./avticle/drip.irrigation rus.html 2011.

DRIVERS AND CONSTRAINTS FOR IMPLEMENTATION BY POLISH FARMERS OF MEASURES TO REMEDIATE NUTRIENT LEACHING TO WATERS

Kiełbasa B.[1], Drangert J.O.[2], Ulén B.[3], Tonderski K.S.[4]

Department of Agriculture and Economics, University of Agriculture in Krakow, Poland [1]
VATEMA Co., Stockholm, Sweden [2]
Department of Soil and Environment, Swedish University of Agricultural Sciences, Uppsala, Sweden [3]
POMInnO Sp. z o.o., Gdynia, Poland [4]

bkielbasa@ar.krakow.pl

Abstract: *Against the background of ongoing eutrophication of the Baltic Sea, this study examined drivers and constraints for implementation by farmers of measures to minimise nutrient losses to waters. The research was conducted in two Polish regions (Mazovia and Pomerania) and included 28 agricultural farms. Four remediation tools were tested and the results evaluated. The study clearly demonstrates the need for greater awareness among farmers of nutrient flows and management on their farms, especially in a changing world requiring them to be better prepared to show flexibility in their production.*

Keywords: FARMERS, PERCEPTIONS, NUTRIENT FLOWS, NUTRIENT LEACHING, SOIL, WATER, NUTRIENT MANAGEMENT

1. Introduction

There are about 1.35 million farms managed by full-time farmers in Poland. Average farm size is 11 hectares (ha) and small farms dominate, with 50% of Polish farms being smaller than 5 ha and only 8% larger than 20 ha [www.arimr.gov.pl]. However, farms larger than 100 hectares occupy 22% of utilised agricultural area (UAA), although they represent only 1% of total number of farms (Figure 1). In general, the smallest farms are situated in southern Poland and the largest in northern and western Poland.

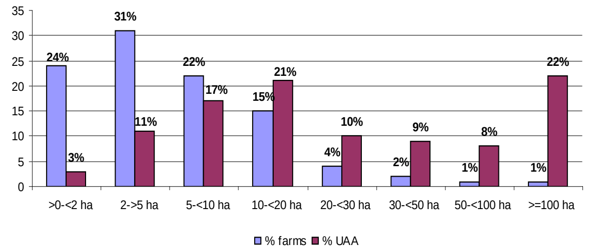


Figure 1: *Percentage of farms in different size classes (blue) and corresponding total utilised area (UAA) in agricultural production in Poland, 2010.* Source: Agricultural Census, Eurostat 2010.

The large number of small farms in Poland is a result of historical circumstances from when Poland was under foreign rule and had a tradition of family farms. However, the topography, soil type and climate are characterised by large regional variations (diversity).

The quality of the soil is another important reason for the large diversity of farm structure. Six quality classes have been distinguished in Poland, based on morphological characteristics, soil properties, location, soil profile construction, soil structure, colour, water relations, pH level, and calcium, phosphorus, magnesium and potassium content (Figure 2).

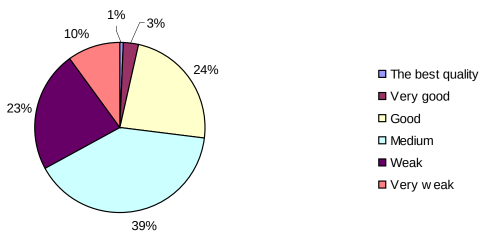


Figure 2: *Agricultural land in Poland (%), divided into six different soil quality classes.* Source: Agriculture in 2015, Central Statistical Office of Poland, 2015.

Farm size, soil quality, region and topography are also factors that significantly affect farm productivity (efficiency and effectiveness). A fragmented agrarian structure compromises farm management, as well as fertilisation and implementation of sustainable agricultural practices.

Some measures can be implemented on-farm to reduce nutrient leaching to waters. These measures primarily relate to rational fertilisation and soil protection, but also concern general farm management, including use of fertiliser, manure and seed and soil tillage (ploughing and soil cultivation) (Pietrzak 2012). To prevent losses of nitrogen (N) and phosphorus (P), farmers can apply a number of methods relating to farm management. For example, they can (Ulén, Pietrzak, Tonderski 2013):

- Store animal manure on concrete pads or in slurry tanks during winter
- Apply fertilisers in a balanced way and in appropriate doses (less than 170 kg N per ha and year, P in relation to soil P status)
- Choose the right time for fertiliser and manure application so that nutrients are available when the crop requires them.

Farmers can also use agro-technical methods to minimise or avoid nutrient leaching, such as:

- Using modern, precise and efficient application equipment for spreading mineral fertilisers, manure and slurry than enables good contact between manure/ fertiliser and soil
- Taking into account weather conditions during application of fertilisers, by avoiding application shortly before heavy rain. Slurry should not be applied on warm days to avoid loss of N to the atmosphere
- Keeping a plant cover on arable land during autumn and winter, e.g. growing a catch crop
- Leaving buffer strips of grass along open ditches and streams
- Limiting soil tillage
- Ploughing in spring instead of autumn, before sowing of spring crops
- Incorporating manure into the soil as soon as possible and applying mineral fertilisers in bands close to the seed
- Applying lime to optimise the pH level of the soil and specialist lime to improve the structure of certain soils.

There are also several recommendations relating to animal production, such as providing appropriate animal nutrient-balanced feed and ensuring adequate construction and equipment in buildings for animals. Other measures relate to the farm surroundings and managing other fields, such as constructing wetlands and sedimentation ponds to reduce N and P losses via water leaving the field. There are also recommendations to keep the farmyard in order and according to pro-environment rules (Ulén, Pietrzak, Ramnerö, Strand 2016).

2. Materials and methods

This study was conducted as part of the pilot project "Baltic Sea 2020: Self-evaluation and risk analysis by farmers concerning losses of nutrients and low-cost remedial measures". The project lasted three years and involved a total of 50 farmers and 26 agricultural advisors from two Polish administrative regions, Pomerania and Mazovia.

Farmers and advisors were introduced to four relatively recent approaches to modifying agricultural practices and management, and reducing P and N losses to waters: 1) Surveys with soil analyses of all fields on the farm, 2) calculation of farm-gate P and N balances, 3) a calculation tool for estimating N leaching risk in individual fields, and 4) a farm walk with an advisor to discuss ways to reduce nutrient losses from small hotspots, such as farmyards, stream banks and erosion-prone areas.

The aim of the present study was to analyse and assess factors influencing implementation of measures to mitigate losses of N and P to waters. The study encompassed 28 agricultural farms from among the 50 included in the project.

Two rounds of interviews (in 2013 and 2015) were conducted using semi-structured questions. The farmers were interviewed in their farmhouse and audio-recorded with their consent. The interview protocol contained 25 questions about each farmer's perception of environmental protection issues and fertiliser management, and about some measures to reduce nutrient leaching to waters. The questions focused primarily on subjective assessments and the farmer's opinion about implementing remediation measures to counter nutrient losses. The second round of interviews also sought to trace changes in the farmer's perceptions compared with the first interview.

3. Results

The average farm size was 45 hectares (range 13-130 ha). Most farmers (72%) did not change their production from 2013 to 2015, so their crop rotation, or main type of agricultural production, remained basically the same. However, eight farmers (28%) had expanded their acreage by leasing land. These farmers tried to manage the leased fields in the same way as their own fields, but in practice this depended on the duration of the lease and its terms. When farmers were asked about improved methods of soil tillage (own fields as well as leased), most responded that it would be possible to manage the soil more efficiently than at present. Only four farmers responded in the negative, and another four were unsure. The latter farmers usually argued that timing their measures was impossible, since the weather is difficult to predict. The positive answers were often supported by mention of measures that the farmer had already adopted. Most farmers were open-minded regarding (in favour of) changes and claimed that something can always be improved or changed.

Soil testing performed by accredited regional laboratories provided data and maps on pH levels and plant-available potassium (K) and P in the soil. All farmers (28) reported that the soil surveys were very useful, and 22 farmers claimed that they now did soil tests regularly (every 1-2 or every 5 years). Four farmers had done a soil survey for the first time, while two farmers stated that it was a long time since they had their soil tested. Twenty farmers now tested their soil for pH and liming requirement and assessed the fertiliser requirement in order to decide the doses of manure and mineral fertiliser to apply.

All farmers confirmed that each crop needs a specific composition of nutrients in the soil or when adding commercial mineral fertilisers. Some farmers gave the following examples: "For each plant the NPK ratio is different", "You have to monitor the soil and take plant observations into account when you calculate the dosage, otherwise the yield will be lower", "I cultivate grass, cereals and maize for silage; cereals and maize take up all the nutrients they need from the soil, a mixture of grass and legumes can fertilise the soil" (Drangert, Kiełbasa 2016). Three farmers agreed about differences in crop requirements, but claimed that it is difficult to monitor this in practice owing to lack of knowledge or external factors such as weather or soil quality that influence the nutrient content in the soil.

Knowledge of nutrient flows on the farm is essential in managing soil and fertilisation. However, the farmers interviewed had rather vague ideas about nutrient flows on their farm, as evidenced by their difficulties in estimating farm-gate nutrient balance. The farmers were assisted by their advisor in completing the sheets and estimating the surplus/deficit of nutrients on their farm. In addition, the Excel spreadsheet was designed to allow them to roughly estimate N leaching in a simplified way, based on factors such as previous year's crop and soil tillage method. Of the 28 farmers interviewed, 23 remembered the idea of farm-gate balance more or less well by the second interview and described it in various ways. They were able to specify the inputs and outputs of nutrients on their farm. Two farmers did not trust the results and therefore relied on own experience to identify amount of nutrients on the farm. Five farmers did not recall the farm-gate balance at all and complained that it was too "academic" and detailed.

The farmers interviewed usually decided the amount and proportions of manure and mineral fertiliser to use on the basis of soil test results. They also relied on their own experience and usually decided how much to use for each field depending on the amount of manure available. They commonly applied as much manure as was produced on the farm, with only a few exporting manure to neighbours. Most farmers examined the content of nutrients in the soil (using the soil test results) and took into account the specific needs of the planned crop. Farmers usually bought mineral N fertilisers to supplement P in the manure or mineral P (K and trace elements) to improve soil fertility. Thus we concluded that they considered the composition of mineral fertilisers. As regards the composition of manure, the farmers usually relied on their experience, since the nutrient composition in manure varies.

Most farmers wanted to extend their farms and improve productivity. Fertilisation is a major factor in such improvement. Farmers' understanding of the intricate interplay between soil, plant and nutrients was assessed already in the first set of interviews. Their views on the composition of cow manure and pig slurry differed significantly. Sixteen farmers claimed that there is a great difference and 13 stated that cow manure is better than pig slurry because, according to them, it contains more P and K than pig slurry. Only two farmers claimed the opposite, stating that pig slurry contains more nutrients which plants can also take up more easily than those in cow manure. Seven farmers (25%) stated there is no major difference in nutrient content between the two types of manure. According to four farmers from this group, pig slurry and cow manure have a very similar content of nitrogen (N) and differ in terms of other nutrients. A further two farmers claimed that the composition of nutrients is almost the same, except for the acidic nature of pig manure. One farmer said that all manure and slurry cause acidification, but cow manure to a lesser extent. Six farmers said that they did not know whether there was any difference or could not decide.

In general, the farmers' understanding and perception of the nutrient content and accessibility of nutrients in manure improved between the two rounds of interviews, conducted in 2013 and 2015.

Nineteen farmers (68%) confirmed that their views on the nutrient content and accessibility of nutrients in manure had changed in recent years. They mentioned several attitudes that had changed (some farmers listed more than one change). The most important change was their attitude to using soil maps and evaluating soil fertility. The second most important change was in mineral fertiliser dosage, as they applied less fertiliser but obtained the same or similar yields. They also mentioned changes in farm management methods in general, and confirmed that it helped to change the whole farm management and to become more effective. The responses were as follows:

- Seven farmers (25%) confirmed the importance of soil mapping for familiarising themselves with soil type and soil fertility
- Seven farmers had realised that they can apply less fertiliser and get the same yield; now they know it is important not to apply too much fertiliser, because this can harm the soil (over-fertilisation),
- Three farmers said that they had learned that different crops and different stages of development need different fertilisers
- Two (7%) farmers had changed mineral fertiliser type and now used better balanced and more expensive fertilisers because these gave higher yield
- Two (7%) farmers applied fertilisers at appropriate times and in appropriate amounts and used a good application technique ("Now I apply fertiliser early in the season to ensure the fertiliser gets into the soil and that plants can take it up through the root system because that's a long process", "I have learned that it's not good to apply lime and phosphorus at the same time")
- Two farmers now use manure more effectively, by using only as much manure as is needed; previously they applied all the manure available, but now they match the amount of N and P to the crops and the soil mapping data.

However, seven farmers (25%) claimed that nothing had changed in recent years. Their view on manure nutrient content and accessibility had not changed in recent years and they managed the soil and nutrients in the same way as in the past. This could be the result of low awareness of the importance of knowledge or reluctance to gain new knowledge. Three of them claimed that they already had all the necessary knowledge and did not want to change their attitude. One farmer cited financial reasons as the main obstacle, claiming that money is the main driver for any change. In addition, two farmers said "I can't say", as if they did not know a simple answer to that question.

Measures to prevent nutrient leaching to waters are usually readily available and simple to apply. Some measures do not require large expenditure, as confirmed by the interviewees. However, implementation of some other measures involves additional costs or workload. Eleven farmers (39%) stated that they did not incur any costs in implementing measures to reduce nutrient losses or they could not specify any costs. Most farmers had already constructed manure pads and/or slurry tanks, usually with the support of EU funds as 82% of the farms concerned were subsidised by the Rural Development Programme for Poland. These funds were allocated for farm modernisation. Purchase of necessary equipment such as spreaders for manure and fertilisers and seed drills had also been subsidised by EU funds or direct payments received by all farmers. Some farmers reported extra costs linked to reducing nutrient losses in the previous three years. These costs were:

- Six farmers had bought a new type of fertiliser that also included e.g. micro-nutrients
- One farmer had renovated a manure pad
- One farmer had prepared a fertiliser plan and ordered soil tests
- One farmer was spending more on soil cultivation because he had started to apply lime on his farm
- Two farmers had spent their own time learning new things (nutrient flows on the farm, difference in crop nutrient requirements, the importance of soil testing) and found it very inspiring.

In addition, one farmer claimed that he did not incur any costs through implementation of pro-environment measures, but rather gained benefits from new knowledge.

3. Discussion

On-farm nutrient flows are determined by a complex system of soil, water, air, chemical reactions and the influence from the crop itself and farming practices. The farmer tries to manipulate this system, mainly to increase crop and animal outputs and make the farm economically viable. Increasing fertiliser prices, environmental regulations and EU subsidies push the management of the farm in one direction, but consideration of nutrient balances on the farm and economic gain may be conflicting. There are general rules of thumb for increasing the efficiency of nutrient management, such as:

- The 'Four R'-rule: fertiliser and manure at *right* dose, *right* place, *right* time and *right* measures
- Keeping manure on pads and slurry in tanks
- Leaving a green strip along water courses and open ditches
- Tillage in spring for spring crops
- Planning fertiliser/manure application considering crop rotation and, especially, the preceding crop
- Minimising the number of passes with heavy equipment on fields, to avoid soil compaction.

Prevention of nutrient losses and implementation of low-cost remedies require certain knowledge. A farmer can use methods that are beneficial in reducing losses without detailed knowledge of each step in nutrient flows. They develop such methods from practical experience or from advice obtained from other farmers, neighbours, agricultural advisors or training courses. From a water quality and Baltic Sea perspective, good practice is what counts, not a detailed understanding by farmers of nutrient flows. However, in a changing world farmers need to be better prepared for flexibility in their production and for introducing changes (searching for new markets, implementing new animal breeds, new cultivation methods, etc.), which may be easier if they are familiar with actual nutrient flows. They may also be more likely to change poor practices if they know the basics of nutrient management.

The farmers interviewed knew most of the general rules for increasing nutrient management and, just like agricultural advisors and researchers, they knew that all measures are site-specific. Therefore, the measures prioritised on their farm may in practice be guided by guesswork and convenience, rather than scientific fact.

The results show different approaches of farmers to improving their farm management and differences in their perceptions of nutrient and fertilisers. These may be related to farm size and type of production. Implementation of pro-environment practices is very often a condition for obtaining subsidies or grants (e.g. from EU funds). Therefore, farmers should start with low-cost measures when it comes to nutrient management optimisation, as well as seeking to avoid nutrient leaching. Other obvious and general limitations are the local climate and soil quality, which determine agricultural practices and dosages.

The main driver for implementation by farmers is that tools are easy to learn and cheap to implement in practice. Farmers can also be driven by measurable (tangible) results, both in terms of improving the environment and saving money on the farm, for example as a result of reducing mineral fertilisation. The role of agricultural advisors is also very important; if they have the appropriate knowledge, they can encourage farmers to implement suitable measures.

Within the study sample, 28% of farmers had introduced one or more measures directly aimed at reducing nutrient leaching, e.g. growing a catch crop, avoiding soil tillage on steep slopes, preparing a fertiliser plan or improving manure storage on their farm to avoid losses. However, the most important impact of the project seemed to be that farmers had become aware that they sometimes apply too much manure and fertiliser, or apply plant nutrients in very far from optimal proportions.

The present analysis focused on farmers' knowledge and perceptions about nutrient losses. Some interviewees, especially younger farmers (10 farmers were under 40 years of age) showed an interest in learning more about how to improve farming and husbandry practices. These younger farmers were willing to take part in training activities and scientific conferences. Their goal was to become more competitive on the market and achieve higher income, so they were prepared to implement innovations or test new solutions on their farms. Most stated that they would like to be involved in similar projects in the future. In contrast, 25% of the farmers aged 55 and above showed less interest in gaining new knowledge or in developing their farms, due to their age.

All farmers interviewed appreciated the soil mapping in helping them to get to know their own soil and apply fertilisers in a good way. However, most farmers found the farm-gate calculations very difficult and some farmers even said that it was necessary to be very knowledgeable or "academic" in order to complete the tables. On the other hand, a soil test was considered clear and easy by farmers, and therefore they used it more willingly. The graphical form of the soil maps was clearer and the laboratory testing made farmers trust the results and adjust application of manure and fertiliser to the map data more willingly.

It can be concluded that there is a clear need for Polish farmers to identify P and N flows on their farms. Systems thinking using farm-gate data represents a relatively recent approach to nutrient management and must be carefully rolled out to farmers over time to facilitate adoption. Implementing low-cost measures for reducing nutrient losses requires a fair understanding of the nature of losses and what is within reach for farmers. However, nutrient losses are only one part of a more comprehensive systems set-up. Analysis of responses obtained in interviews with farmers revealed possible ways to improve farm practices in order to raise productivity and reduce environmental harm simultaneously. A major challenge seems to be that farmers would benefit from a better (systems) understanding of nutrient behaviour/flow on their farm. Soil surveys, maps showing N leaching from different fields and other ways of showing the risk of leaching through observations (farm walks) are tools that can provide such insights and enhance farm practices, as well as systems understanding.

References

Agricultural Census, Eurostat 2010.

Statistical Yearbook of Agriculture in 2015, Central Statistical Office of Poland, 2016.

Drangert, J-O.;Kiełbasa, B. *Self-evaluation and risk analysis by farmers concerning losses of nutrient and low cost remedial measures*. Report 2. Post-project interview study. BalticSea2020. May, 2016.

www.arimr.gov.pl, *The Agency for Restructuring and Modernisation of Agriculture in Poland*, ARMA,

Ulén, B.; Pietrzak, P.; Tonderski, K.S. *Self-evaluation of farms for improved nutrient management and minimized environmental impact - a handbook.* Institute of Technology and Life Sciences in Falenty, 2013, ISBN 978-83-62416-67-7 pp 77-84, http://www.balticsea2020.se

Ulén, B.; Pietrzak, S.; Ramnerö, B.; Strand, L. *Agricultural soil acidity and phosphorus leaching risk at farm level in two focus areas*. Acta Agriculturae Scandinavia, Section b - Soil & Plant Science, 2016.

Pietrzak, S. *Priority measures to reduce nitrogen and phosphorus losses from agriculture to protect water quality*. Report of Institute of Technology and Life Sciences in Falenty, Poland 2016.

IRRIGATION SCHEDULING FOR MAIZE UNDER CHAINGING NORTHERN BLACK SEA CLIMATE

Prof. Eng. Zornitsa Popova, PhD. DSc.[1] Assist. Prof. Eng. Maria Ivanova, PhD. [1]
[1] N. Poushkarov Institute of Soil Science, Agrotechnology and Plant Protection (ISSAPPNP), BG - 1080 Sofia, Bulgaria[2]

zornitsa_popova@abv.bg

Abstract: *The region of Varna proved to be a driest in terms of precipitation in this country. Trend test applied to climate datasets reviled a significant increase for seasonal* ***reference evapotranspiration ETo*** *during 1970-2004. Detected climate variability&droughts create uncertainties for maize irrigation scheduling and harvested yield. To cope with them, simulations have been performed for past (1951-1984) and present (1951-2004) weather conditions using the validated water balance WinISAREG simulation model for two maize hybrids of different sensitivity to water stress grown on a Haplic Chernozem soil of medium water holding capacity. The study compares three irrigation scheduling alternatives built in agreement with past studies to develop environmentally sound/water saving irrigation technologies that consist of refilling the soil reservoir by adopting a* ***management-allowed depletion fraction*** *(****MAD****): (1) MAD=0.50; (2) MAD=0.33; (3) MAD=0.50 but partially refilling the soil reservoir. Simulations relative to the very high irrigation demand year of the current weather show that when aiming at maximum yield all three scheduling alternatives require the same* ***irrigation depths ID****=360mm that is 60 mm higher than conventional advised in the region. In the average demand years of past and current weather, Alternative 1 requires the same* ***ID****=270mm while a smaller* ***ID****=240mm is simulated with both alternatives 2 and 3 due to the fact that* ***available soil water ASW*** *is presently depleted to the* ***optimum yield threshold OYT*** *at harvest.*

Keywords: CLIMATE VARIABILITY/CHANGE, NORTHERN BLACK SEA COAST, IRRIGATION SCHEDULING, MAIZE, WINISAREG MODEL, WATER SAVING, YIELD

1. Introduction

Varna agricultural region, situated in the Northern Black Sea climate zone, proved to be exceptionally dry in term of annual and seasonal precipitation (Alexandrov (Ed) 2011; Slavov et al, 2004; Popova (Ed) 2012; Popova et al.2014; 2015). Trend test applied to local climate data shows that relative to reference evapotranspiration ***ETo-PM*** for maize crop season, a significant trend of increase by +2.6 mm yr^{-1} is observed for the period 1970-2004 (Fig.1b).

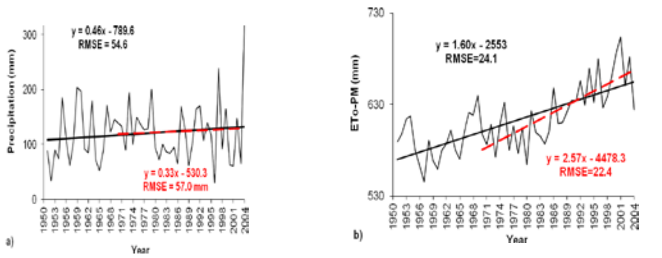


Fig. 1 *Variation of: (a) Precipitation sum for "June-August" period (mm) and (b) Seasonal ETo-PM "May-Sept" (mm), (——), Varna; trends relative to 1951-2004 (——) and 1970-2004 (— —).*

Detected climate variability and change (Fig.1) creates uncertainties for maize irrigation scheduling and harvested yield there. To cope with them, simulations have been performed for past (1951-1984) and present (1951-2004) weather conditions using the validated irrigation scheduling simulation WinISAREG model (Pereira et al., 2003) for two maize hybrids that were subject of former studies, the semi-early Pioneer P37-37 and the late H708, considering a wide spread Haplic Chernozem soil in the region (Popova et al., 2006b; Stoyanov, 2008; Boneva in Popova (Ed), 2012 Popova et al., 2014).

2. Materials and Methods

The WinISAREG model, as described by Pereira et al. (2003), uses the soil water balance approach and the updated methodology proposed by Allen et al. (1998) to compute crop ***ET*** and irrigation requirements. Data required consist of: (1) weather data on precipitation and reference evapotranspiration ***ETo***; (2) soil water data, the ***total available soil water*** (***TAW***, mm m^{-1}), i.e. the difference between soil water storage at ***field capacity FC*** and ***wilting point WP*** for a soil depth of 1.0 m, and (3) crop data relative to the main crop development stages and corresponding dates, crop coefficients ***Kc***, root depths and the soil water depletion fractions for no stress ***p***. The model allows various simulation options including to simulate an irrigation schedule using selected irrigation thresholds, executing the water balance without irrigation, computing ***net irrigation requirements NIR.Relative yield decrease*** due to water stress ***RYD*** is estimated by Stewart one-phase model (1977) when ***yield response factor Ky*** is known.

Data on soil genesis&texture, ***FC, WP***, bulk density (Table 1) are used to define the *water holding capacity of the soil* ***TAW=157 mm m^{-1}*** in the study (Boneva in Popova (ed.) 2012).

Table 1. *Main soil hydraulic properties relative to a Haplic Chernozem soil, North East Bulgaria* (Stoyanov, 2008).

Horizon	Depth, *cm*	Bulk density at ***FC***, *g cm^{-3}*	Soil moisture, *fractions in weight*	
			Field capacity	*Wilting point*
A1	0-10	1.14	0.25	0.12
	10-20	1.19	0.26	0.12
	20-30	1.33	0.24	0.12
A2	30-50	1.35	0.24	0.13
	50-70	1.35	0.24	0.12
A3	70-115	1.44	0.23	0.12

The previously validated crop parameters, as described by Popova et al. (2006b), Popova (2008), Popova and Ivanova in Popova (ed.) (2012), have been presently used after respective adaptation to local climate and soil conditions (Table 2).

Table 2. *Dates of maize development stages and respective crop coefficients (****Kc****) and soil water depletion fractions for no stress (****p****) for maize grown on a Haplic Chernozem soil in the Varna region.*

Growth phases	Initial period	Mid-season	End-season
Dates	26/04 to 19/05	15/07 to 09/08	30/09 (harvest)
Kc	0.28	1.28	0.35
p	0.45-0.75	0.65	0.80

The report compares several irrigation scheduling alternatives built in agreement with past studies to develop environmentally sound and water saving irrigation technologies that avoid soil cracking by maintaining soil moisture above 75% ***FC***, high non-uniformity of water distribution, water and yield losses (Popova et al., 1994; 1998; Popova&Kuncheva, 1996; Varlev et al., 1998): Alternative (1) consists of refilling the soil reservoir by adopting a management-allowed depletion fraction ***MAD***=0.50, i.e. to 76% ***FC***, and 90 mm application depth tuned to continuous furrow irrigation (Fig.2a); Alternative (2) consists of refilling the soil reservoir by adopting a smaller ***MAD***=0.33, i.e. to 84% ***FC***, and 60 mm application depth relative to sprinkler or surge furrow irrigation of improved distribution uniformity and reduced application depth (Fig.2b); Alternative (3) aims at better storage of seasonal precipitation by adopting ***MAD***=0.50 and partially refilling soil reservoir to 83%***FC*** with 60 mm application depth (Fig.2c).

According to the regional irrigation practice (Zahariev et al, 1986), the last allowed irrigation date is 21/08 for an average and a high irrigation demand year having ***probability of exceedance of irrigation depth*** $\boldsymbol{P_I}$=50% and $\boldsymbol{P_I}$=25% and 31/08 for the year of very high irrigation demand ($\boldsymbol{P_I}$=10%). These conditions are considered for all studied irrigation scheduling alternatives in addition to a free definition of irrigation timing aiming at water saving while avoiding yield losses. Alternative (4) refers to the option crop without irrigation. Climate data observed on a daily basis, namely minimum and maximum air temperature $\boldsymbol{T_{max}}$ and $\boldsymbol{T_{min}}$, relative air humidity, wind speed and solar radiation computed by using the temperature difference method with coefficient $\boldsymbol{K_{Rs}}$=0.19 adjusted to "coastal" location (Allen et al. 1998) are used when simulating irrigation scheduling alternatives referred above. As a second option, monthly precipitation and ***ETo*** series (1951 to 2004), with ***ETo*** computed as described in Popova et al. (2006a), have been used to build probability curves of occurrence of a ***NIR*** and respective ***RYD*** relative to rainfed maize semi-early and late hybrids (Fig.3).

3. Results and Discussions

The results of simulations of ***ASW*** for the three irrigation scheduling alternatives are presented in Figs.2a 2b 2c for **1953** that is a very high demand year ($\boldsymbol{P_I}$=8%) of the past climate 1951-1984 (Fig.3b). If aiming at maximum yield, irrigation scheduling alternative 1 requires 4 irrigation events of 90 mm and alternatives 2 and 3 require 6 events of 60 mm, thus the same demands ***ID***=360 mm for all three alternatives (full line refers to the last irrigation applied before 31/08). However if a negligible yield decrease ***RYD***<1% is accepted (dashed line in Figs. 2b 2c), alternatives 2 and 3 fully cover conventional crop irrigation timing and demands ***ID***=300 mm (Zahariev et al.1986) and ***NIR***=315 mm.

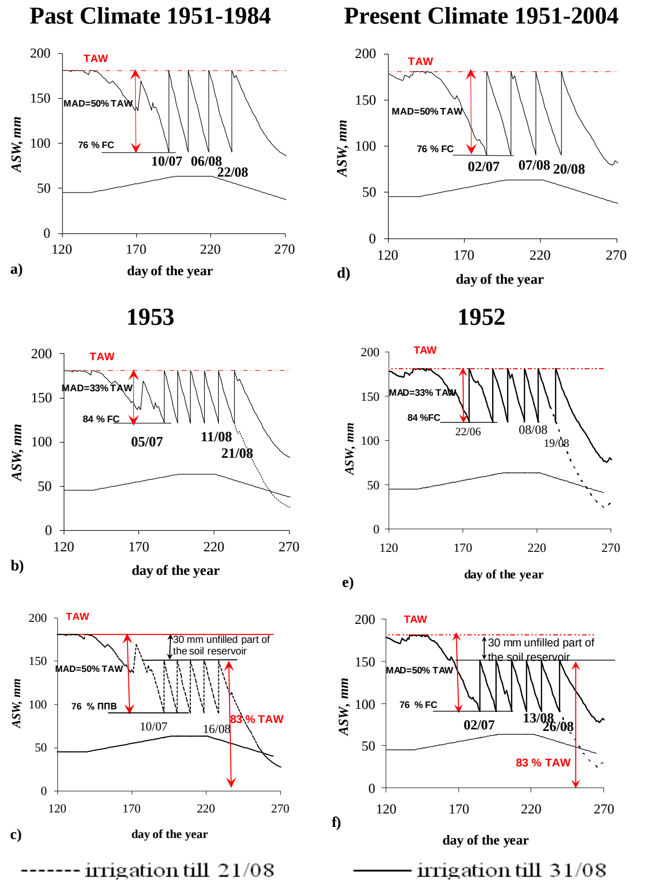


Fig.2. *Available soil water* (***ASW,*** *mm) for the three irrigation scheduling alternatives in* ***the very high irrigation demand 1953 and 1952 (***$\boldsymbol{P_I}$***=8 %)*** *relative to past (1951-1984) and present (1951-2004) weather: a) and d) alternative 1; b) and e) alternative 2; and c) and f) alternative 3, with identification of the date of the first and last irrigation; The horizontal dashed line, above, corresponds to* ***TAW*** *and the broken line, below, to the non-stress* ***OYT*** *threshold.*

Simulations for **1952** representing the very high irrigation demand year in the last 54 years ($\boldsymbol{P_I}$=7%, Fig. 3a) show that a larger yield decrease occurs when keeping up with presently advised irrigation demands of 300 mm (the dashed line in Figs.2e 2f). Adaptation to changing climate consists of an earlier timing for first irrigation event that requires a seasonal irrigation depth of 360 mm.

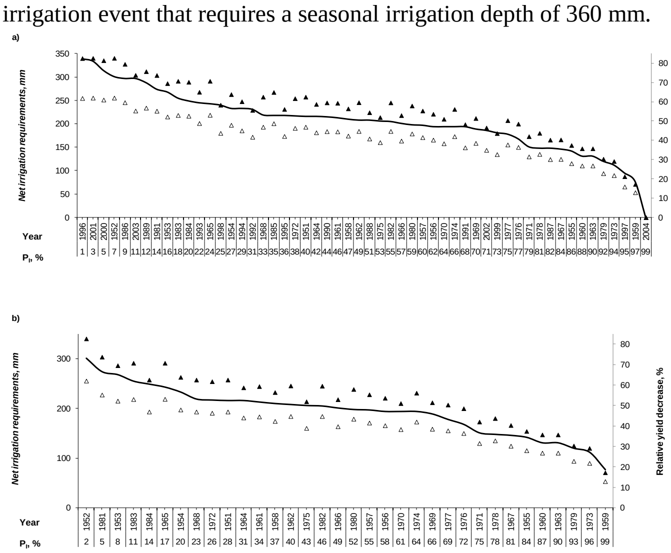


Fig. 3 *Probability curves of occurrence of a Net Irrigation Requirements,* ***NIR****, mm, (—) and Relative Yield Decrease of rainfed maize,* ***RYD****,%, comparing the semi-early P37-37 (Δ), Ky=1.2, and late H708 (▲), Ky=1.6, hybrids relative to two periods: a) 1951-2004; b) 1951-1984; Simulations when average monthly air temperature Tmax, Tmin and Precipitation data are used.*

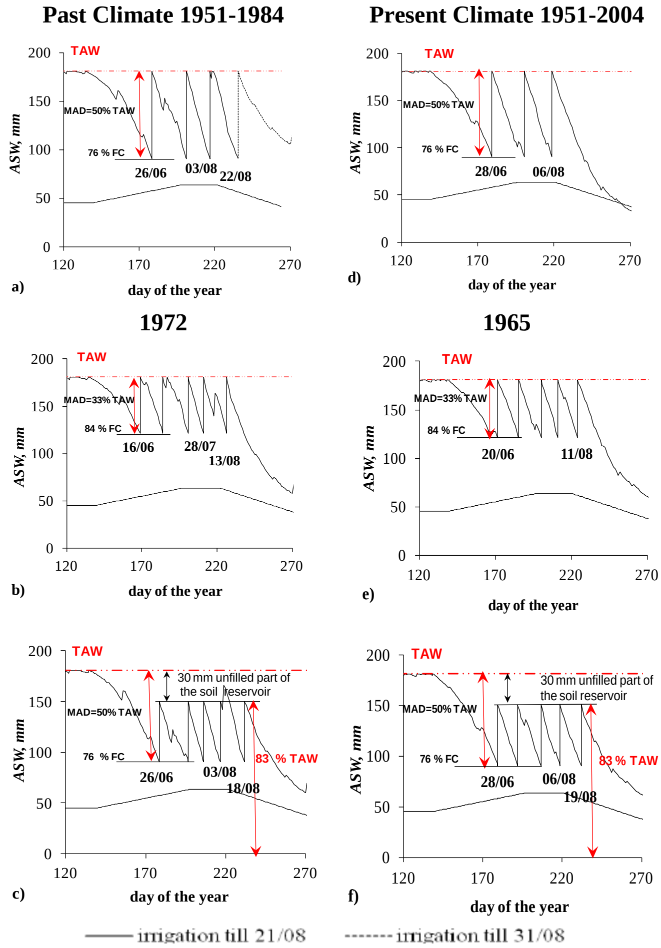


Fig.4. *Available soil water* (***ASW,*** *mm) for the three irrigation scheduling alternatives in* ***the high irrigation demand 1972 and 1965 (***$\boldsymbol{P_I}$***=25 %)*** *relative to past (1951-1984) and present (1951-2004) weather: a) and d) alternative 1; b) and e) alternative 2; and*

c) and f) alternative 3, with identification of the date of the first and last irrigation;

Comparing *ASW* (Fig.4) and summary of results (Table 3) for all alternatives for the high irrigation demand year (***P**$_I$*=25%) relative to past (**1972**) and present (**1965**) climate conditions show that alternative 1 results in a different date of last irrigation (22/08 *vs*. 6/08), number of required irrigation events (4 *vs*.3) and depths (360 *vs*.270 mm) and ***ASW*** at harvest (130 *vs*.31 mm). Contrarily, alternatives 2 and 3 adapt better to climate uncertainties requiring the same ***ID***=300 mm regardless unfavorable distribution of seasonal precipitation in 1965 (Figs.4b 4c 4e 4f; Table 3). Referring to Alternative 2, it fully covers again currently adopted irrigation timing and demands, as described by Zahariev et al. (1986).

Results of *ASW* simulations for the average demand year (***P**$_I$*=50%) in the period 1951-1984 (**1980**) and in the last 54 years (**1975**) are shown in Fig.5. Relative to the high demand **1972** (Figs.4a 4b 4c) the number of irrigation events reduces from 4, 5 and 5 to 3, 4 and 4 for alternatives 1, 2 and 3 respectively. Thus irrigation scheduling alternative 1 requires the same irrigation depths of 270 mm (Figs.5a 5d) while alternatives 2 and 3 save water requiring 240mm (Figs.5b 5c 5e 5f; Table 3). Comparing alternativ es 1 and 3 that have the same ***MAD***, the higher ***ASW*** at harvest and irrigation demand for alternative 1 result from the fact that application depths for this one are larger than for the other (90 mm *vs*. 60 mm). Abundant spring rainfalls in 1975 are not accommo dated in the root zone while the available soil water ***ASW*** is depleted to optimum yield threshold ***OYT*** at harvest (Table 3).

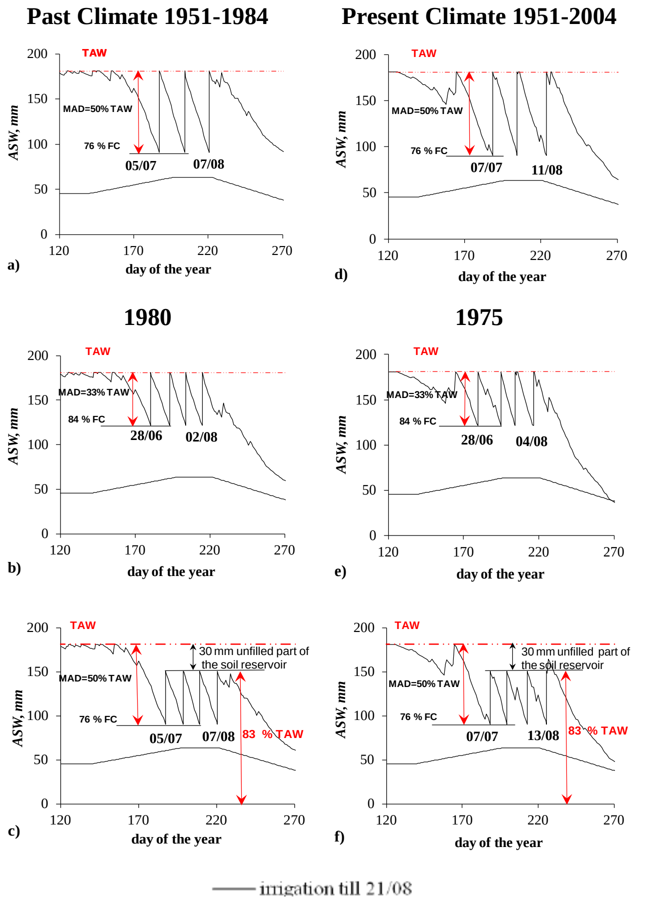


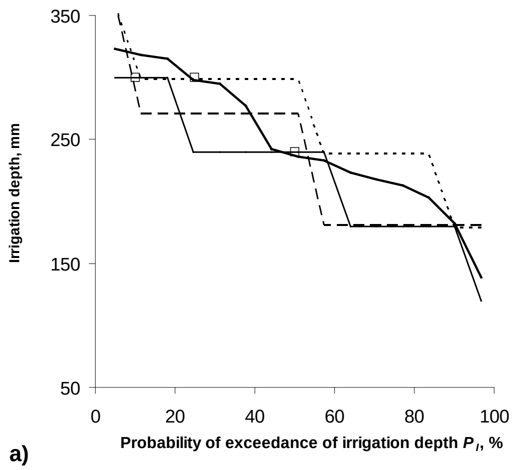
Fig.5. *Available soil water (**ASW,** mm) for the three irrigation scheduling alternatives in **the average 1980** and **1975** (**P**$_I$=52%) relative to past (1951-1984) and present (1951-2004) weather: a) and d) alternative 1; b) and e) alternative 2; and c) and f) alternative 3, with identification of the date of the first and last irrigation.*

Referring to each year of the past weather in 1951-1984, ***NIR*** ranges from 80 mm for the very wet 1959 *(**P**$_I$*=99%*)* to 150-210 mm in the moderate demand years *(40<**P**$_I$<75%)* reaching 300 mm in the very dry 1952 *(**P**$_I$*=2%, Fig.3b*)*. Relative to rainfed maize, *H708 variaty*, same period, yield decrease ***RYD*** varies within the limits of 20% in 1959 to 40-60% in the average years reaching 83% in the extreme demand 1952 (Fig.3b). Semi-early maize hybrids, as *Pioneer (P37-37)* and *Kn-2L-611*, mitigate yield losses to 40<***RYD***<45% in the average and 62% in the very high irrigation demand years. Climate change in the last 54 years is characterized by a higher frequency and intensity of drought, larger number of extremely dry years with maximal ***RYD*** for maize without irrigation (4 *vs.* 1 in the past) and increased ***NIR*** in average and dry seasons of ***P**$_I$≤75%* by 30-35 mm (Figs.3a 3b).

Table.3 *Summary water balance and relative yield decrease,**RYD**,relative to irrigation scheduling alternatives 1, 2, 3 and rainfed alternative 4 for the average and high irrigation demand years, 1951-1984* and 1951-2004. Last allowed irrigation date 21.08.*

Climate conditions	***Average irrigation demand***								***High irrigation demand***							
	Past				**Present**				**Past**				**Present**			
	1951-1984				**1951-2004**				**1951-1984**				**1951-2004**			
Year	**1980***				**1975**				**1972***				**1965**			
***P**$_I$*, %, **1951-2004**	59%				**53%**				38%				**24%**			
P**$_I$*, %, **1951-1984	**52%**				43%				**26%**				17%			
Prec. May-Sep,mm	**166**				**209**				**158**				**135**			
Prec. Jul-Aug, mm	**56**				**86**				**66**				**35**			
Net irrigation requirements, mm	**219**				**231**				**280**				**277**			
Irrigation alternatives	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Season Irrigation Depths (***ID***), ***mm***	***270***	***240***		*0*	***270***	***240***		*0*	***360***	***300***		*0*	***270***	***300***		*0*
№ irrigation events	***3***	***4***	***4***	***0***	***3***	***4***	***4***	***0***	***4***	***5***	***5***	***0***	***3***	***5***	***5***	***0***
Crop evapotranspi-ration (***ETa***), ***mm***	***484***			***293***	***539***			***339***	***534***			***287***	***502***			***255***
Non-used precipitation, mm	***34***				***158***		***144***		48	***33***			***60***			
ASW harvest, mm	***97***	***65***		***17***	***63***	***35***	***46***	***6***	***130***	***84***		***32***	***31***	***58***		***8***
RYD,%, ***Ky***=1.32	*0*	*0*	*0*		*0*	*0*	*0*		*0*	*0*	*0*		*0*	*0*	*0*	
RYD,%, ***Ky***=1.2				***47***				***47***				***56***				***59***
RYD,%, ***Ky***=1.6				***63***				***59***				***74***				***79***

Fig.6 illustrates the simulated results relative to 15 consecutive years when using full required climate data series observed on a daily basis.



a)

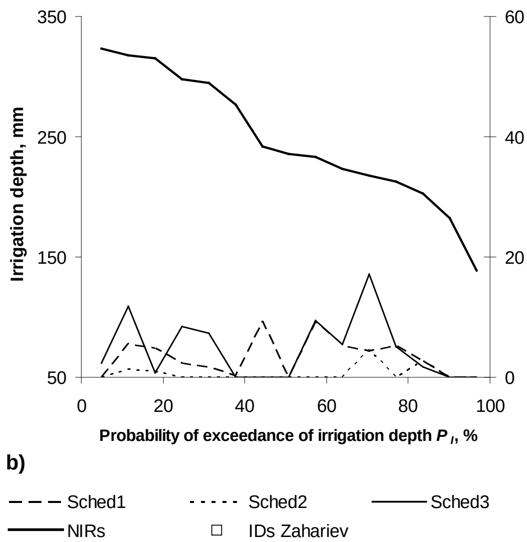


Fig.6. *Irrigation Demand,* ***ID****, mm, (a) and relative yield decrease,* ***RYD****, %, computed with* ***Ky****=1.32 (Popova and Pereira, 2011)(b) relative to irrigation alternatives 1,2 and 3 simulated with 21/08 as a last allowed irrigation date, sorted in relation to* irrigation depth *1951-1965 using all required climate data observed on a daily basis*

The respective irrigation thresholds and application depths produce demands that are mostly different among them (Fig.6a). Simulations for each year during the period have shown that Alternative 3 allowing a larger soil water depletion (***MAD***=0.50) and partially refilling the soil reservoir leads to better storage of precipitation requiring 60 mm less irrigation water than the one having ***MAD***=0.31. The water saving effect of Alternative 1 (***MAD***=0.50) varies between 30 in dryer (P_I<55%) and 60 mm in wetter (P_I>60) seasons. Simulation results are compared to irrigation scheduling presently advised in the region (Zahariev et al.1986) showing that the latter covers ***ID*** computed with alternative 2 in the high and very high demand years (Figs. 6a). The impacts on yields caused by the irrigation alternatives are also different among them (Fig.6b) being larger with schedule 3 (***RYD***=11.4% on the average, maximal ***RYD***=17.1% in 1955) and negligible with schedule 2 (average ***RYD*** =0.6%, maximal ***RYD***=4.6%). Referring to rainfed maize, the results indicate that coping with droughts and scarce water resources by adopting the less sensitive to water stress semi-early maize hybrids results in loosing up to half of yield potential (Fig.7).

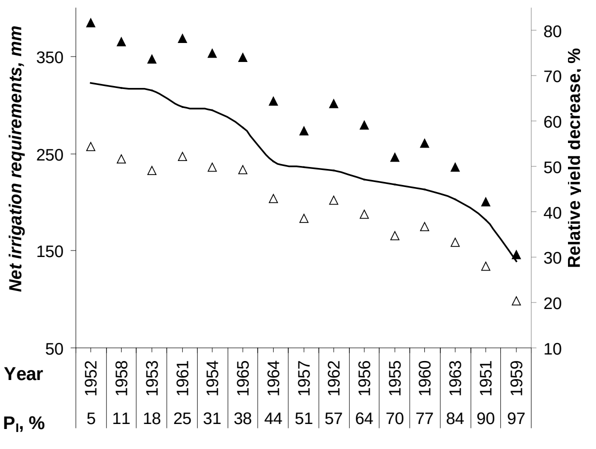


Fig.7. RYD *of rainfed maize, comparing the semi-early P37-37 (Δ),* ***Ky****=1.2, and late H708 (▲),* ***Ky****=1.6, hybrids,1951-1965 using all required climate daily data sorted in relation to probability of* ***NIR****.*

4. Conclusions: To assess how past (1951-1984) and present (1951-2004) weather conditions could affect irrigated maize crop in Varna region, simulations of several precise irrigation scheduling alternatives and a rainfed option were performed for a Haplic chernozem soil of medium water holding capacity. For the period of past climate 1951-1984 ***NIR*** ranges from 80 mm in the very wet 1959 to 150-210 mm in the average seasons (40≤P_I≤75%) reaching 300 mm in the very dry 1952 (P_I=2%). ***NIR*** has increased by 30-35 mm in the average and high demand years having P_I≤75% in the period 1951-2004. Simulations when using all required climate daily data show that rainfall is not fully used, particularly in the average years, because it falls during the earlier stages of the crop development, when irrigation demand is low and the soil water content is high. Adaptation of irrigation to changing climate consists of precise irrigation timing and demand evaluation for high and very high demand years, including planning the first irrigation event before conventional date. Application of irrigation scheduling alternative 2 leads to less impact on yield but requires 30-60 mm more irrigation water than the water saving alternatives 1 and 3.

5. References

Alexandrov V.(ed), 2011. Methods for monitoring and estimation of drought vulnerability in Bulgaria.Nat.Inst.Meteo&Hydr.,Bulg.Acad.Sci, Sofia:216p.(Bg)

Allen R.G, L.S.Pereira, D.Raes, M.Smith, 1998. Crop Evapotranspiration – Guide lines for Computing Crop Water Requirements. *Irrig.&Drain. Paper* **56**,FAO, R.

Gregorič G. (Ed.), 2012. Drought management centre for South-east Europe – DMCSEE Summary of Project results, 55 p., Slovenian Environ. Agency.

Pereira L.S.,P.R.Teodoro,P.N.Rodrigues,J.L.Teixeira, 2003.Irrig.Scheduling simulation: the model ISAREG, in G.Rossi,L.S.Pereira,A.Zairi (Eds.), *Tools for Drought Mitigation in Medite. Regions*, Kluwer, Dordrecht, pp. 161-180.

Popova Z., I.Varlev, I.Gospodinov, 1994. Surge irrigation as an environment friendly technology. *Reg.Europ.Conf. ICID*, Varna, Bulg., **3 (**48): 341-350.

Popova Z., R. Kuncheva, 1996. Modeling in Water Losses Evaluation for Nonhomogeneous Furrow Set. (ASCE) *J. of Irr.and Drain.Eng*, **122** (1):1-6.

Popova Z., I.Varlev , V. Kutev E. Ikonomova, 1998. Irrigation and cropping techniques to prevent natural water pollution. Papers *1st Inter-Regional Conf.* "*Environment - Water:* Innovative Issues in Irr.&Dr.", Lisbon, : 6-13.

Popova, Z., M. Kercheva, L.S. Pereira, 2006a. Validation of the FAO methodology for computing ETo with limited data. Application to South Bulgaria. *Irrig. and Drain*. **55** (1): 201-215.

Popova Z, Eneva S., Pereira L.S., 2006b. Model validation, crop coefficients and yield response factors for irrigation scheduling based on long-term experiments. *Biosystems Engineering*. **95** (1): 139-149.

Popova Z.,L.S. Pereira, 2008. Irrigation scheduling for furrow irrigated maize under climate uncertainties in the Thrace plain,Bulgaria, *Bios.Eng*.**99**(4):587-597.

Popova, Z., 2008. Optimization of irrigation scheduling, yields and their environmenttal impacts by crop models, Synthesis of DSc Thesis with extended summary in English, "N. Poushkarov" Institute of Soil Science, S: 100 p.

Popova Z,L.S.Pereira, 2011.Modelling for maize irrigation scheduling using long term experimental data from Plovdiv region,Bulg.*Agr.Wat.Mngm* **98** (4):675-683.

Popova Z.(ed)2012. Risk assessment of drought in agriculture and irrigation management through simulation models.'N. Poushkarov'ISS,S:242 (Bg,En).

Popova Z., Ivanova M., Martins D., Pereira L.S., Kercheva M., Alexandrov V., Doneva K., 2013. Climate change, agricultural drought and irrigation requirements in Bulgaria. "*Water Affairs*" Magazine **1/2:**14-22 (Bg).

Popova Z., Ivanova M., Martins D., Pereira L.S., K. Doneva, Alexandrov V., Kercheva M., 2014. Vulnerability of Bulgarian agriculture to drought and climate variability with focus on rainfed maize systems, *Natural Hazards*, **74** (2):865-886 Springer Science+Business Media Dordrecht.

Popova Z, Ivanova M, Pereira L, Alexandrov V, Kercheva M, Doneva K, Martins D, 2015. Droughts and climate change in Bulgaria: assessing maize crop risk and irrigation requirements in relation to soil and climate region. *BJAS*, **21**(1):35-53.

Slavov N, Koleva E, Alexandrov V, 2004. The climate of drought in Bulgaria. In: Knight GG, Raev I, Staneva M (eds.) *Drougth in Bulgaria: a contemporary analog for climate change*.Ashgate Publ.Lim, Aldershot: 39–52.

Stewart J.L., Hanks R.J., Danielson R.E, Jackson E.B., Pruitt W.O, Franklin W.T., Riley J.P., Hagan R.M., 1977. Optimizing crop production through control of water and salinity levels in the soil. Report PRWG151-1, Utah State Univ., Lo.

Stoyanov P. 2008. *Agroecological potential of maize cultivated on typical soils in Bulgaria*.Habilitation thesis,"N. Poushkarov"Inst. of Soil Science, S:249 p. (Bg)

Varlev, I., 2008. Potential, efficiency and risk under maize cultivation in Bulgaria. Academy of Agriculture, Sofia, 128 p. (Bg)

Varlev I.,Popova Z.,Gospodinov I., 1998. Furrow surge irrigation as water saving technique.In L.S.Pereira&J.Gowing(Eds.)"Water&Env:Inn.Issues in Irr&Drai",S elected papers*1st Inter-Reg.Conf."Env.- Wate"*,L:131-140(E&FNSpon-Routledge).

Zahariev T, Lazarov R, Koleva S, Gaidarova S, Koichev Z,1986.Raionirane na polivnia rejim na selskostopanskite kulturi[Regional irri.scheduling of agric.crops:646.Zemizdat.

BIOREMEDIATION OF OIL POLLUTED SOILS BY INDIGENOUS BACTERIA AT SUPLACU DE BARCAU, ROMANIA

Prof. Dr. Eng. Puia Carmen [1], PhD. Popa M. [2], Eng. Faur C. [2], Lecture Dr. Eng. Pop Rodica[1]
USAMV Cluj Napoca, Romania [1] Stilo Evora SRL Marghita, Romania [2]
Email: carmen.puia@usamvcluj.ro, marian.popa@usamvcluj.ro, faur.claudiu@stiloevora.ro, rodica.pop@usamvcluj.ro

***Abstract**. Bioremediation is the enhancement of live soil organisms as fungi, bacteria and plant to break down hydrocarbon and organic contaminants. For achieving the bioremediation method one took soil samples with different concentrations of petroleum products, from different parts of the petroliferous exploitation Suplacu de Barcau. Out of these collected soil samples, the microorganisms were isolated and analyzed all their characters and for identification were used the Galleries API 20E, 20NE and 20Strep. The obtained pure cultures were tested on agar media enriched with different concentrations of crude scaffolding oil, as the sole source of carbon. The bacteria that were validated in this study constituted then the bacterial consortium used for bioremediation. This consortium was applied on polluted soil with initial different TPH concentration. Regarding the initial concentration of mineral oils and extractable petroleum products, this varies in a very large range but during the whole bioremediation process, one noticed a decrease of the petroleum products concentration.*

KEYWORDS: BIOREMEDIATION, OIL POLLUTED SOILS, BACTERIA

1. Introduction

Petroleum hydrocarbons (PHC) released into the environment can pose risk to ecosystems and human health. The hydrocarbons (PHC and PAH - polycyclic aromatic hydrocarbons) are a class of toxic pollutants that have accumulated in the environment due to both natural and anthropogenic activities (Kästner, 2000). They are mainly produced from incomplete combustion of organic materials, fossil fuels, petroleum product spillage and various industrial activities, and partly also from natural processes such as forest fires and volcanic eruptions. Some compounds in petroleum products are known to be mutagenic and carcinogenic. Petroleum and its product enter the soil via crude oil pipe leakages, oil tank ruptures and indiscriminate disposal of refinery products leading to changes in soil properties (Trofimov and Rozanova, 2003). Crude oil is a highly complex mixture of hydrocarbons amounting to hundreds of individual compounds with different chemical structure and molecular weight plus a series of lower molecular weight compounds other than hydrocarbons (phenols, thiols, naphthenic acids, for example heterocyclic compounds with N (pyridines, pyrrole, indole etc.), compounds with S (alkyl thiols, thiophene, etc.). Soils polluted with petroleum hydrocarbon (PHC) are low in fertility and hence, do not support adequate crop growth and development (Abii and Nwosu, 2009).

Bioremediation is a widely accepted method of remediation because it is an environmentally friendly method that requires less cost and techniques. To a large extent, bioremediation equally accomplishes complete clean-up of the polluted soil. When compared with other conventional remediation techniques, results have shown that bioremediation reduces PHC concentrations in polluted soils with minimum site disturbance and at lower costs (Buzea and DeStefanis, 2001). Bioremediation is the enhancement of live soil organisms as fungi, bacteria and plant to break down hydrocarbon and organic contaminants. Many microorganisms have the ability to use gaseous hydrocarbons, liquid and solid aliphatic series, asphalt and aromatic as the sole source of carbon and energy and they decompose these in water, CO2 and lower molecular weight compounds. Bacteria and fungi are the main microorganisms responsible for biodegradation of petroleum hydrocarbons (Abbassi and Shquirat, 2008). Generally, the biological methods for the remediation of petroleum hydrocarbons are based on the cooperation of more bacterium species because a pure culture of bacteria has not the metabolic ability to easy degrade certain compounds or it does not have the necessary biomass needed to degrade fast enough the toxic compounds.

The objective of our study was to isolate and identify species of indigenous bacteria from the polluted soils of the petroliferous exploitation site Suplacu de Barcau, Romania, to test their biodegradable capacity *in vitro* and *in vivo*.

2. Material and methods

There were randomly collected 6 soil samples at depth of 0-15 and 30-60 cm as follows: 4 points from the petroliferous site, 2 points from sludge sediment and 1 point form unpolluted soil (as control). Subsamples of 1g were suspended in 99 ml of 0.1% saline solution, agitated on a water-bath shaker (100 rpm at 28^{o}C for 30 min). A serial decimal dilution was performed to 99 ml of 0,1 % saline solution. Aliquots of 0.1 ml from each dilution were transferred on different types of agar medium: Topping, Nutrient Agar (Merk), Thornton, Pseudomonas agar F Base and Pseudomonas agar P base. The morphological characterization of each isolate was first performed by noticing cultural, morphological and tinctorial characters (color, size, colony characteristics - form, margins and elevation and Gram staining reaction). The microscopically examination revealed bacilli, coccobacillus and cocci Gram stained positive and negative. For identification there were used biochemical tests with different API Galleries (20E, 20NE and 20Strep). The bacteria were tested in vitro for the biodegradable capacity on mineral medium Difco Bushnel-Hass enriched with different quantities of oil from Suplacu de Barcau (2ml/l – mineral medium I and 5 ml/l – mineral medium II). The bacteria that were validated in this study formed the bacterial consortium used for bioremediation. This consortium was applied on polluted soil from Suplacu de Barcau, with initial different TPH (total petroleum hydrocarbon) concentration in two experiments. In the first experiment were collected 7 samples of polluted soil form Suplacu de Barcau and for the monitoring of the bioremediation were used flasks in 3 replicates. In every flask was introduced 100g polluted soil, inoculated it with 20 ml bacterial consortium and agitated 24 hours for homogenization. The TPH content was monitored during the bioremediation process at 8, 18 and 24 weeks. In the second experiment of 175 days were collected 5 types of polluted soils from Suplacu de Barcau area. 10 kilo of each soil, in 3 replicates were placed in transparent boxes and inoculated with 2000 ml of bacterial consortium.

Before applying the consortium, in both experiments, at all the soil samples were determined the physicochemical properties and the TPH (1-st experiment), mineral oils (2 experiment) and EPH (extractable petroleum products – 2-nd experiment) by GC-FID and FTIR methods of the soil samples collected for bioremediation.

3. Results

We`ve isolated 15 bacterial strains. The bacteria isolated from the polluted soil of Suplacu de Barcau which showed good and very good results, in the terms of their ability in the biodegradation of hydrocarbons consisted of species of the following genera: *Alcaligenes, Arthrobacter, Acinetobacter, Bacillus, Brevibacterium, Clostridium, Corynebacterium, Flavobacterium, Mycobacterium, Micrococcus, Pseudomonas and Streptomyces.* The microbial consortium was created of these bacteria. We can see in table 1 and figure 1 the in vitro testing of the bacteria ability to degrade the crude oil from Suplacu de Barcau.

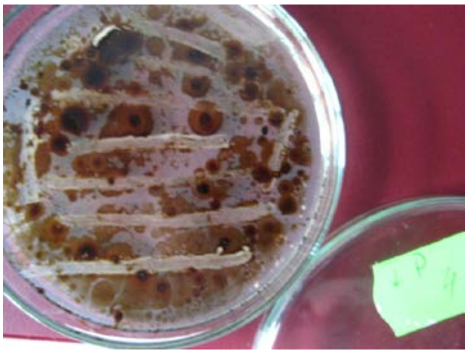


Figure 1. In vitro testing bacteria ability of oil degradation

Table 1. *The evolution of bacterial strains on mineral media enriched with crude oil*

Bacterial strains	Mineral medium I		Mineral medium II	
	without oil	with oil	without oil	with oil
1	+	+	+	+
2	+	+	-	-
3	+	+	+	+
4	+	+	-	+
5	+	0	-	0
6	+	+	+	-
7	-	+	-	+
8	+	+	+	+
9	+	+	0	+
10	+	0	0	0
11	+	+	-	+
12	+	+	-	+
13	+	+	-	+
14	+	+	0	0
15	-	+	-	+

This consortium was applied in flasks, on polluted soil with initial different TPH concentrations. The initial concentration of crude oil varies in a very large range, from 8850 to 73700 (in sludge sediment) exceeding the intervention threshold (2000 mg/kg) for soils with less sensible usages as we can observe in table 2.

Table 2. *The evolution of TPH (mg/kg) in polluted oil soil samples under the influence of bioremediation (experiment 1)*

Sample	TPH (mg/kg) after:			
	0 week	8 weeks	18 weeks	24 weeks
S1	46600	44300	27000	22000
S2	37600	35000	19000	14000
S3	21500	21000	5700	5700
S4	8850	5500	1400	1200
S5	21500	19400	13700	9750
S6	9670	7800	1500	1400
S7	73700	69000	66000	62000

Along the bioremediation process in all the variants the TPH decreased with the increasing of the contact time between the soil and the microorganisms.

For studying the dynamics of the TPH we`ve calculate the percentage of TPH remained in samples after every stage of bioremediation, considering 100% the initial concentration of TPH in every sample. As we can see in table 3 in soils with TPH between 0-10000 mg/kg (S4 and S6) the concentration decreased with 85%. In samples with TPH between 10000 – 50000 mg/kg (S1, S2, S3, and S5) the oil content decreased variable between 26 and 47%. The smallest decrease (15%) was found in sludge sediment.

Table 3. TPH percentage remained in polluted soil samples during the bioremediation

Sample	TPH percentage after:			
	0 week	8 weeks	18 weeks	24 weeks
S1	100	95.1	57.9	47.2
S2	100	93.1	50.5	37.2
S3	100	97.7	26.5	26.5
S4	100	62.1	15.8	13.6
S5	100	90.2	63.7	45.3
S6	100	80.7	15.5	14.5
S7	100	93.6	89.6	84.1

The dynamics of this process is presented in figure 2. We can observe that after a period of adaptation between the components of the consortium and with the new source of nutrition (weeks 0-8) when the decrease of TPH was slower, follows a period of intense decrease (weeks 8-18). In the last period of bioremediation, weeks 19-24, the decrease was slower again, maybe because of the low volume of soil.

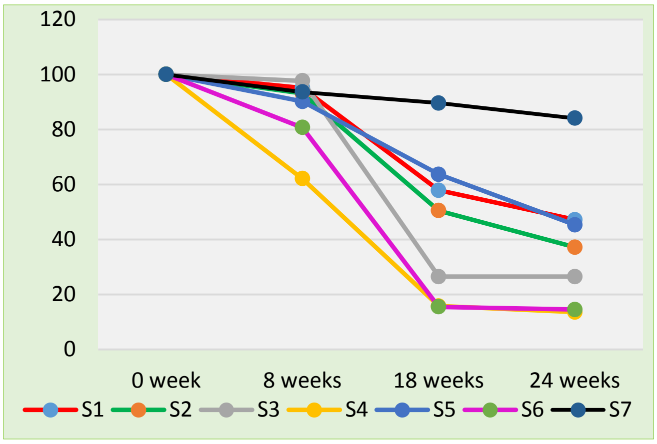


Figure 2. *The variation of TPH from polluted soil samples during the bioremediation period (experiment 1)*

Table 4. *The evolution of mineral oils content (mg/kg) in polluted oil soil samples under the influence of bioremediation (experiment 2)*

Sample	Mineral oils (mg/kg) after:			
	0 day	63 days	125 days	175 days
S1	47667	42333	35000	31000
S2	28667	26333	23667	19667
S3	16000	13667	13500	10667
S4	3733	3267	2933	2833
S5	7333	6933	6733	6267

Data regarding the second experiment of bioremediation are presented in table 4 (mineral oils) and 5 (EPH) and figure 3 (mineral oils) and 4 (EPH).

In table 4 we can observe that the initial mineral oils content varies between 3733 and 47667 mg/kg and decreases constantly in all the soil samples.

The evolution of the bioremediation process, presented in figure 3, show us a continuous decrease of the mineral oils content. This decrease is more pronounced in the samples with higher initial concentration of oil. After 63 days from inoculation the content of mineral oils decreases with 2-12%. In the next stage the decreasing is slow too, in 4 variants with the exception of variant S1 where the decrease is of 32%. In the last stage of bioremediation, after 50 days the decrease is more pronounced, between 29 and 46%. So, after 175 days of bioremediation the content of mineral oils decreased with 42-66% and the highest decrease was in the sample with maximum level of contamination – S1.

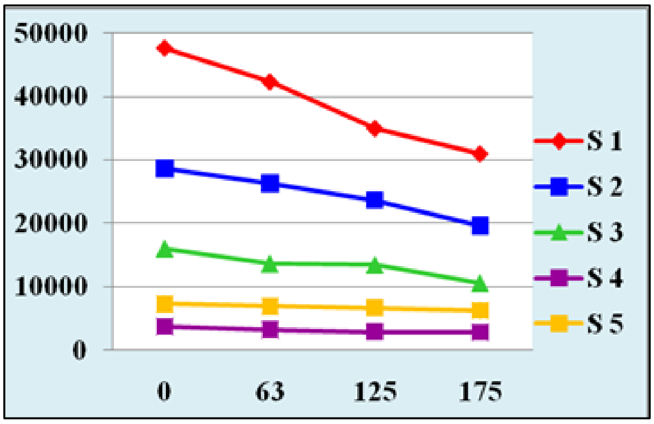


Figure 3. *The variation of mineral oils (mg/kg) content during the bioremediation process (experiment 2)*

The levels of the EPH as we can see in table 5 and figure 4 are lower than those of the mineral oils in all the samples. The evolution of the EPH is characterized by constant and slow decrease in the first 125 days as we could see at the evolution of the content of mineral oils but after 175 days the decrease is significant.

Table 5. *The evolution of EPH (mg/kg) in polluted oil soil samples under the influence of bioremediation (experiment 2)*

Sample	EPH (mg/kg) after:			
	0 day	63 days	125 days	175 days
S1	32000	31233	29667	11333
S2	16967	15300	12933	6167
S3	10800	9733	6467	3333
S4	3500	3367	2233	1143
S5	4867	4300	4267	2833

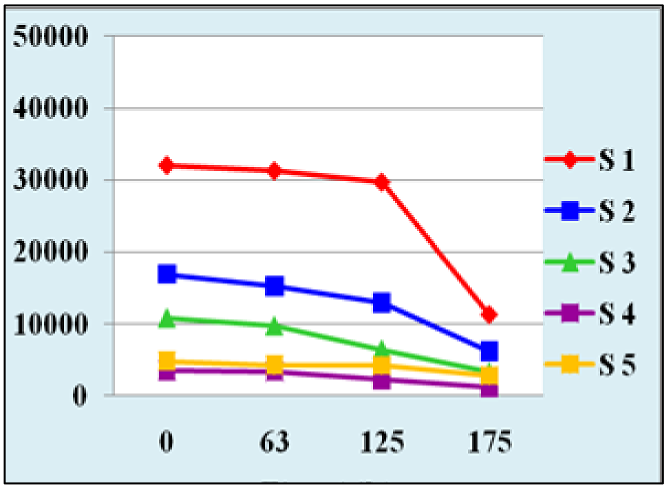


Figure 4. *The variation of EPH (mg/kg) during the bioremediation process (experiment 2)*

4. Conclusion

Generally, the biological methods for the remediation of petroleum hydrocarbons are based on the cooperation of more bacterium species which use the crude oil hydrocarbons as carbon source.

In the first experiment because of the low quantity of soil the bioremediation capacity of the consortium leveled in the last stage.

In the second experiment the bacterial consortium isolated from the polluted soil determines a decrease of the content of mineral oils with 15-30% and of the EPH with 30-60%. To decrease the values of TPH under the intervention threshold (2000 mg/kg) we can either continue the process of bioremediation or we can increase the added quantity of consortium/ soil unit.

6. Literature

Abbassi, B.E., W.D. Shquirat, 2008, Kinetics of indigenous isolated bacteria used for Ex-Situ bioremediation of petroleum contaminated soil, Water Air Soil Pollut., 192:221–226;

Abii, T. A., P. C. Nwosu, 2009, The effect of oil-spillage on the soil of Eleme in Rivers State of the Niger Delta area of Nigeria, Research journal of environmental sciences, 3(3), pp 316-320;

Bsnks, M.K., K.E. Schultz, 2005, Comparison of plants for germination toxicity tests in petroleum - contaminated soils, Water, Air and Soil Pollution 167: 211-219;

Buzea, D. C., E. J. DeStefanis, 2001, Accelerated Bioremediation as an Alternative to Conventional Remedial Technologies, Leggette, Brashears and Graham, Inc., White Plains, New York;

Kästner, M., 2000, Degradation of aromatic and polyaromatic compounds. In H.-J. Rehm and G. Reed (eds) Biotechnology, Vol. 11b, Wiley-VCH, Weinheim, Germany. 211–23;

Trofimov, S.Y., M.S. Rozanova, 2003, Transformation of soil properties under the impact of oil pollution, Eurasian Soil Science, 36, pp S82-S87.