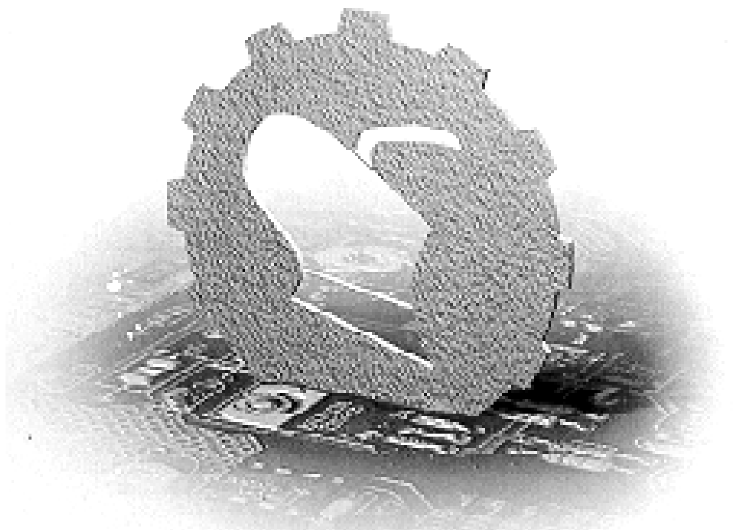
ISSN 0554-5587
UDK 631 (059)

ПОЉОПРИВРЕДНА ТЕХНИКА

AGRICULTURAL ENGINEERING

НАУЧНИ ЧАСОПИС
SCIENTIFIC JOURNAL



УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
INSTITUTE OF AGRICULTURAL ENGINEERING

Година XXXIX Број 3, 2014.
Year XXXIX, No. 3, 2014.

Издавач *(Publisher)*
Универзитет у Београду, Пољопривредни факултет, Институт за пољопривредну технику, Београд-Земун
University of Belgrade, Faculty of Agriculture, Institute of Agricultural Engineering, Belgrade-Zemun

Контакт подаци уредништва *(Contact)*
11080 Београд-Земун, Немањина 6, тел. (011)2194-606, 2199-621, факс: 3163-317, 2193-659, e-mail: gogi@agrif.bg.ac.rs, жиро рачун: 840-1872666-79.

11080 Belgrade-Zemun, str. Nemanjina No. 6, Tel. 2194-606, 2199-621, fax: 3163-317, 2193-659, e-mail: gogi@agrif.bg.ac.rs , Account: 840-1872666-79

ПОЉОПРИВРЕДНА ТЕХНИКА

НАУЧНИ ЧАСОПИС

AGRICULTURAL ENGINEERING

SCIENTIFIC JOURNAL

УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ

UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
INSTITUTE OF AGRICULTURAL ENGINEERING

WEB адреса

www.jageng.agrif.bg.ac.rs

Техничка припрема *(Technical editor)*

Иван Спасојевић, Пољопривредни факултет, Београд

Лектура и коректура: *(Proofreader)*

Гордана Јовић

Превод: *(Translation)*

Весна Ивановић, Зорица Крејић, Миљенко Шкрлин

Штампа *(Printed by)*

"Академска издања" – Земун

Часопис излази четири пута годишње

Тираж *(Circulation)*

350 примерака

Pretplata za 2015. godinu iznosi 2000 dinara za institucije, 500 dinara za pojedince i 100 dinara za studente po svakom broju časopisa.

Радови објављени у овом часопису индексирани су у базама *(Abstracting and Indexing)*:

AGRIS i SCIndeks

Издавање часописа помогло *(Publication supported by)*

Министарство просвете и науке Републике Србије

Na osnovu mišljenja Ministarstva za nauku i tehnologiju Republike Srbije po rešenju br. 413-00-606/96-01 od 24. 12. 1996. godine, časopis POLJOPRIVREDNA TEHNIKA je oslobođen plaćanja poreza na promet robe na malo.

S A D R Ž A J

C O N T E N T S

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 1 – 11

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 1 – 11

UDK: 627.13

Originalni naučni rad
Original scientific paper

MODELING OF THE SOIL-RIGID WHEEL INTERACTION USING DISCRETE ELEMENT METHOD

Krisztián Kotrocz[*], **György Kerényi**

Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Machine and Product Design, Hungary

Abstract: In this paper the soil-rigid wheel interaction was analyzed using Discrete Element Method (DEM). Three types of soil model were created with different mechanical properties. After that, the rigid wheel was simulated in two different ways: in the first case it was created as a rigid wall and then as a rigid particle. In each calculation the sinkage of the wheel was measured under different vertical loads. After that, the results of the simulations were compared to the theoretical values. To determine the theoretical sinkage values the Bekker-formula was used. Finally the accuracy and the calculation times of the two simulation methods were compared to each other.

Key words: *DEM, soil, wheel, sinkage, Bekker-formula*

INTRODUCTION

The agricultural machines are come into contact with the soil by their wheels. Therefore the soil-wheel interaction is a very important phenomena which need to be investigated. In the previous century this interaction could be analyzed only by real field or laboratory tests, but the disadvantages were, that performing these tests was very expensive and requires a lot of time. As results some theories were born in the middle of the 20th century about the wheel's sinkage and the rolling resistance. These theoretical backgrounds were summarized by McKyes [1] and Sitkei [2] as well.

In addition the information technology has evolved a lot since the middle of the latest century. Numerical methods were developed as well to simulate the behavior of the materials under static or dynamic loading conditions. These simulations need a lot of

[*] Corresponding author. E-mail: kotrocz.krisztian@gt3.bme.hu

computing time but nowadays it is possible to use these efficiently to simulate the materials. The best known is the Finite Element Method (FEM), but the granular assemblies can not be modeled with FEM because of the structure of the material. The soil consists of a bunch of very small soil-particles which slide and roll on each other during motion.

Therefore the most suitable numerical method to simulate the soil is the Discrete Element Method (DEM) which was published by Cundall and Strack [3]. In DEM the materials are modeled as a group of individual elements which have own displacements. The whole loading process is divided into small time steps and in each calculation cycle the particles' displacements can be determined according to Newton's second law. After that, the displacements at the next time step can be approximated using the so-called central differential method. During our work the PFC2D software was used where only non-deformable elements can be generated thus it is important to define the correct contact type between the elements. According to the previous researches [4-6] the Parallel Bond contact model was used to simulate the soil's cohesive behavior. This type of contact model was developed by Potyondy and Cundall [7] and was published in 2004.

There are two different ways to investigate the soil-wheel interaction with the PFC2D software. The wheel can be simulated as a wall element or in the other case it can be modeled as a rigid particle. In this paper these two simulation methods were compared to each other. In our earlier researches [8] three types of soil model were developed by calibrating the contact properties to the given soil's mechanical parameters (cohesion and internal friction angle). The wheel was pressed into these three soil models and during the simulations the sinkage of the wheel was measured. After that, the results were compared to the theoretical values which can be calculated using the so-called Bekker-formula.

MATERIAL AND METHODS

Theoretical background

In the 20th century Bekker was the first who investigated the soil-tire interaction. He found out that a tire with sufficiently high pressure acts as a rigid wheel and its sinkage can be calculated with Eq. 1 [9]:

$$z = \left[\frac{3 \cdot N}{(3-n) \cdot b \cdot k \cdot d^{0,5}} \right]^{\frac{2}{2 \cdot n + 1}} \quad (1)$$

The meanings of the letters are summarized in Tab. 1. The n *[-]* and k *[Pa·m^{-n}]* denote soil constant and stiffness constant, respectively and they depend on the quality of the soil and the width of the tire. The soil material can be described with its cohesion and internal friction angle values thus it will be very useful if the values of these constants can be attached only to the mechanical parameters of the material. So the k *[Pa·m^{-n}]* stiffness parameter can be calculated as follows:

$$k = \frac{k_c}{b} + k_\phi \qquad (2)$$

The k_c $[Pa \cdot m^{-(n-1)}]$ and k_ϕ $[Pa \cdot m^{-n}]$ are soil stiffness constants as well, but they are not depending on the wheel's geometry. In the book of McKyes [1] there is the Appendix 4, where the values of these constants can be found with the soil's mechanical parameters as well. From there, three types of soil were chosen as it is shown in Table 2. With these data the theoretical value of the wheel's sinkage with given geometry can be calculated.

Table 1. The meanings of the quantities in Bekker-formula

Quantity sign	Unit	Description
z	m	Sinkage of the wheel
N	N	Load of the wheel
n	-	Soil constant
b	m	Width of the wheel
d	m	Diameter of the wheel
k	$Pa \cdot m^{-n}$	Soil stiffness constant
k_c	$Pa \cdot m^{-(n-1)}$	Soil stiffness constant
k_ϕ	$Pa \cdot m^{-n}$	Soil stiffness constant

Table 2. The mechanical parameters and the stiffness-constants of the three soils [1]

Description / Stiffness constant	Unit	Soil-type nr. 1	Soil-type nr. 2	Soil-type nr. 3
Cohesion (c)	kPa	1.7	4.8	11.0
Internal friction angle (ϕ)	°	29.0	20.0	25.0
k_c	$Pa \cdot m^{-(n-1)}$	5.0	52.0	11.0
k_ϕ	$Pa \cdot m^{-n}$	1514.0	1127.0	1802.0
n	-	0.7	0.9	0.7

Settings of the simulations

To investigate the soil-tire interaction the soil model need to be created. Our purpose was to simulate three types of soil which are described with their mechanical properties in Tab. 2. In our earlier work [8], the contact parameters were calibrated to the chosen cohesion and internal friction angle values. In PFC 9 parameters have to be added to define the Parallel Bond contact model, these can be seen in Tab. 3. After that, a numerical direct shear simulation method was developed and many studies were performed. From the results of these tests the soil model's two mechanical properties can be calculated using the theory which was published by McKyes [1] and Sitkei [2] as well. The results are shown in the chapter Results and Discussion.

Table 3. The settings of the discrete element simulations [8]

Geometrical parameters				
Walls (box and rigid wheel)				
Length of the box	mm	300.0		
Height of the box	mm	60.0		
Width of the box	mm	40.0		
Diameter of the wheel	mm	160.0		
Width of the wheel	mm	40.0		
Balls				
Number of balls	-	5000		
Radius of the elements	mm	0.66...1.5		
Mechanical parameters				
Walls (box and rigid wheel)				
Normal stiffness	$N \cdot m^{-1}$	$1 \cdot 10^{20}$		
Shear stiffness	$N \cdot m^{-1}$	$1 \cdot 10^{20}$		
Balls				
Friction coefficient	-	0.5		
Density	$kg \cdot m^{-3}$	1900		
		Soil type nr. 1	Soil type nr. 2	Soil type nr. 3
Ball normal stiffness	$N \cdot m^{-1}$	$7 \cdot 10^6$	$4 \cdot 10^6$	$1 \cdot 10^7$
Ball shear stiffness	$N \cdot m^{-1}$	$7 \cdot 10^6$	$4 \cdot 10^6$	$1 \cdot 10^7$
Parallel Bond normal stiffness	$Pa \cdot m^{-1}$	$7 \cdot 10^6$	$4 \cdot 10^6$	$1 \cdot 10^7$
Parallel Bond shear stiffness	$Pa \cdot m^{-1}$	$7 \cdot 10^6$	$4 \cdot 10^6$	$1 \cdot 10^7$
Parallel Bond normal strength	Pa	$2 \cdot 10^5$	$1 \cdot 10^5$	$5 \cdot 10^5$
Parallel Bond shear strength	Pa	$2 \cdot 10^5$	$1 \cdot 10^5$	$5 \cdot 10^5$
Parallel Bond radius	-	0.5		

After the numerical direct shear tests a new box was created with 5000 particles. The calibrated contact parameters were added to the model and after that, one of the Otico's press wheel was assigned from [10] for further investigations. In the first case the wheel was modeled as a rigid wall and was compressed into the soil with different vertical loads in range of 30 to 300 N. At this type of simulations the so-called servomechanism had to be used to control the force of the wall-element. This calculation method can be found in the technical manual of the PFC2D software [11]. In every calculation cycle the wheel force can be calculated from the contact forces of the wall. After that, the vertical velocity of the wheel has to be adjusted to reach the given loading force. To calculate this velocity with Formula 4 the so-called gain parameter has to be determined from the contact stiffness values:

$$g = \frac{\alpha}{k_{wall} \cdot N_{contact} \cdot \Delta t} \quad (3)$$

$$v_{wheel} = g \cdot \left(F_{wheel} - F_{req}\right) \quad (4)$$

In Eq. 3, *g [-]* is the gain parameter, *α [-]* is the relaxation factor and was set to 0.5 to guarantee the stability of the calculation according to [11]. $N_{contact}$ *[-]* is the number of the contacts of the tire, k_{wall} *[N/m]* is the average stiffness of these contacts and *Δt [s]* denotes the value of the time step. F_{wheel} *[N]* and F_{req} *[N]* are the wheel-force at the given calculation cycle and the requested load of the tire, respectively. The simulations were stopped if the F_{wheel} force approximate to the F_{req} force with the accuracy of 0.5 %. In addition the geometrical and the mechanical properties of the simulations were shown in Tab. 3 and in Fig. 1 as well.

Figure 1. The geometrical dimensions of the Otico press wheel [10]

At the other type of the simulations the press wheel was simulated as a rigid particle. In case of these simulations the servomechanism was not necessary to use. Instead of that, the density *(ρ_{wheel} [kg·m^{-3}])* of the tire-element was calculated from the load and the volume of the wheel with Eq. 5:

$$\rho_{wheel} = \frac{F_{req}}{9.81 \cdot V_{wheel}} = \frac{F_{req}}{9.81 \cdot \left(\frac{d^2 \cdot \pi}{4} \cdot b \right)} \tag{5}$$

The meanings of the *b [m]* and *d [m]* parameters can be seen in Tab. 1 and the multiplier of 9.81 is necessary to calculate the wheel's weight in N-s from its mass in kg-s. After that, the gravity was added to the model to sink the tire into the soil. Finally the simulations were stopped if the velocity of the tire-element decreased under the value of 0.01 mm·s^{-1}. In Fig. 2 the Y position and the Y velocity of the tire and the wheel force were illustrated as green, blue and red line, respectively according to the number of calculation cycle. It can be seen clearly, that the value of the velocity and the position decreased at the start of the simulation. After the 2.75 E6th time steps the Y position of the tire and the wheel force are not changing, thus the wheel got into equilibrium state. So the sinkage of the wheel can be determined.

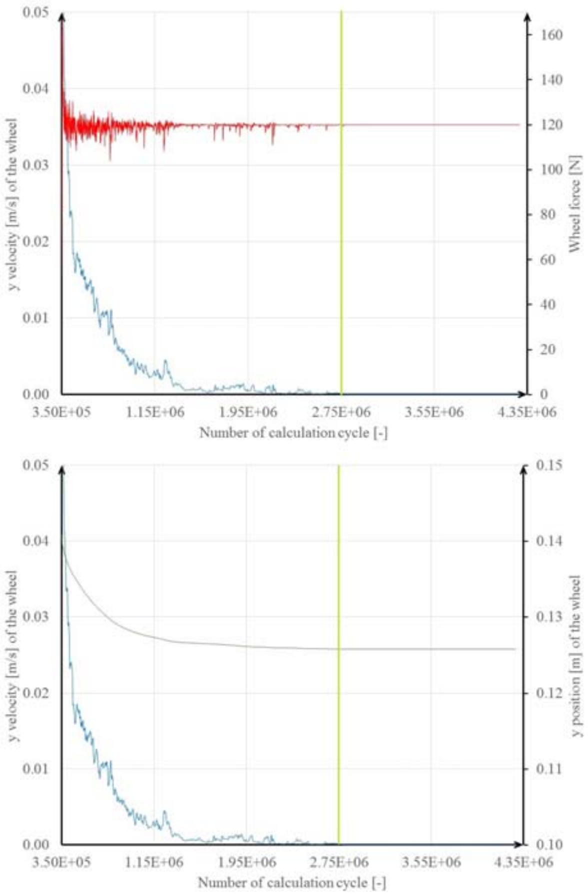


Figure 2. The changes of the Y position, Y velocity of the tire and the wheel force during the "ball-type" simulation in case of soil type nr. 1

During all simulations (the "wall-"and the "ball-type simulations" as well) the vertical position, the velocity of the wheel and the tire force were measured. The results can be seen in the next chapter.

RESULTS AND DISCUSSION

First the results of the numerical direct shear tests are presented. In Fig. 3 the 2D shear box can be seen in case of the soil type Nr. 1. The particles were represented as red and between them there are the tensile forces (the so-called parallel bond forces) as blue lines. The thicknesses of these lines are proportional to the magnitudes of the tensile forces. It can be seen that there are parallel bond forces only near the shear zone, so the simulations gave the same results as the real direct shear tests.

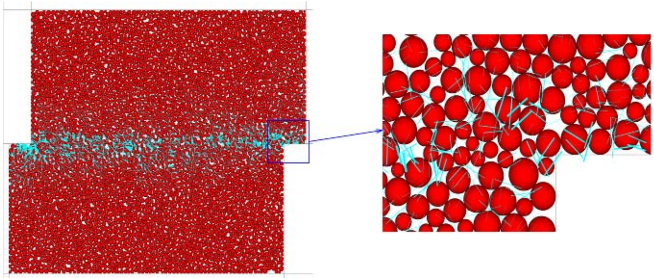


Figure 3. Results of numerical direct shear test in case of soil type nr. 1 [8]

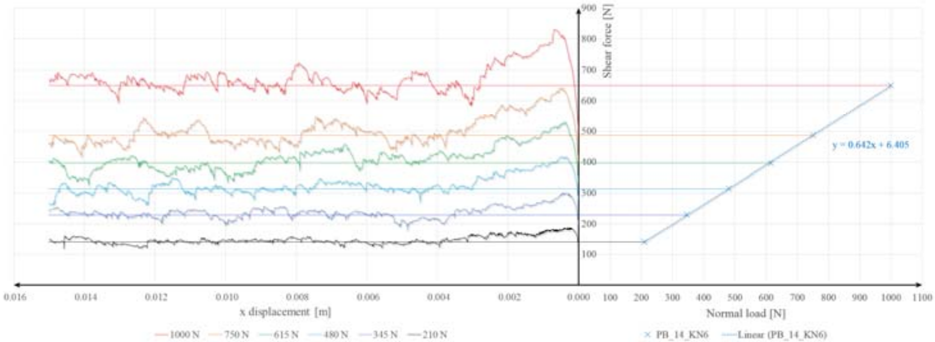


Figure 4. Results of the earlier researches in case of soil type nr. 1 [8]

On the left side of Fig. 4 the shear force was represented according to the shear displacements in case of each normal load (210 N, 345 N, 480 N, 615 N, 750 N and 1000 N, respectively). From a certain shear displacement value the shear forces were not changing sufficiently, so an average shear force value can be determined in case of each simulation. Illustrating these according to the normal loads, the so-called Coulomb-line can be drawn (see on the right side of Fig. 4). The soil's two mechanical properties can be calculated from the equation of these lines. The intersection of the vertical axis and the Coulomb-line defines the cohesion and the angle of the line and the horizontal axis defines the internal friction angle [1, 2].

Table 4. The calculated mechanical parameters of the three soil-model [8]

Description	*Unit*	*Soil type Nr. 1.*	*Soil type Nr. 2.*	*Soil type Nr. 3.*
Cohesion (c)	*kPa*	*1.78 (1.7)*	*5.09 (4.8)*	*7.52 (11.0)*
Internal friction angle	*°*	*32.70 (29.0)*	*31.84 (20.0)*	*31.84 (25.0)*
Relative error of the cohesion	*%*	*4.7*	*6.0*	*31.6*
Relative error of the internal friction angle	*%*	*12.8*	*59.2*	*27.4*

These calculations were performed in each three soil-model, the results can be seen in Tab. 4 (the chosen values from McKyes were represented in parentheses). In case of soil type nr. 1 the two mechanical parameters were calibrated well, but there were bigger errors of them in the other two cases. The details of these results were published in [8].

After calibrating the contact parameters to the soil's mechanical properties, the two types of the soil-wheel interaction simulations were performed. The results of them are shown in Figs. 5-9. In Fig. 5 the Y displacement of the rigid wheel was illustrated in case of vertical load of 120 N. On the left side the "ball-type" simulation, on the right side the "wall-type" simulation was represented. It can be seen that both of the two simulation methods gave the same results. The vertical displacement of the wheel and the soil's particles were very similar in both simulations. There was a difference as well, in case of the "ball-type" simulation the tire moved horizontally to the left a little bit therefore there were greater vertical displacements in the left side of the soil material (see the greater red-zone at the left side of Fig. 5).

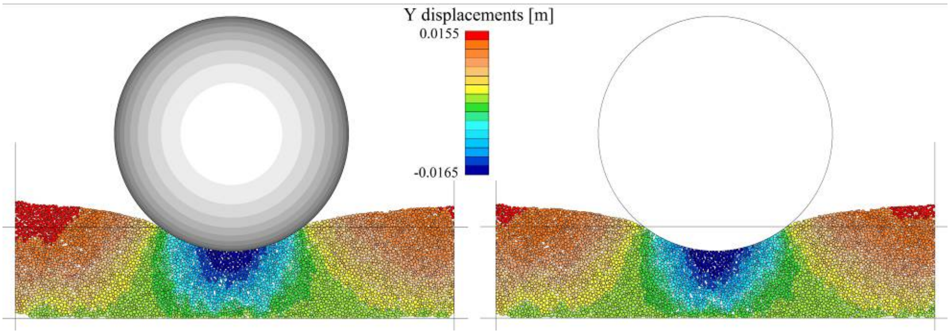


Figure 5. Results of the simulations in case of soil type nr. 1, vertical load of 120 N and "ball-type" simulation (left) and "wall-type" simulation (right)

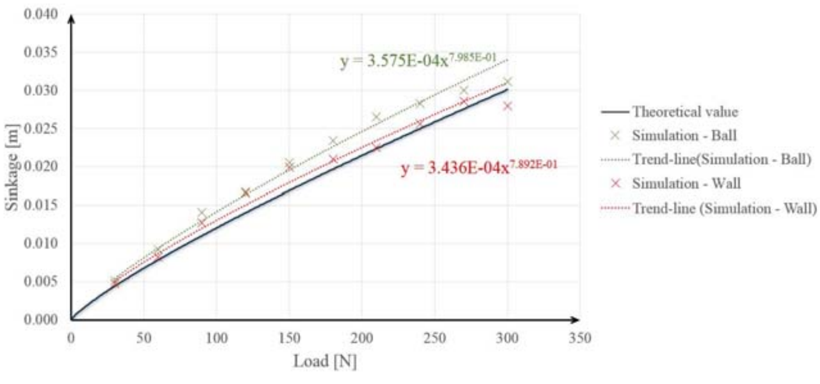


Figure 6. Results of the soil-wheel interaction simulations in case of soil type nr. 1

In Figs. 6-8 the sinkage values were represented in case of all soil types. The simulations were performed with 10 different vertical loads (30 N, 60 N, 90 N *etc.* up to 300 N with positive difference value of 30 N). The results were illustrated as *"X"* in the figures. A trend-line can be fitted to these points using the Wald-method in case of all soil-types. These trend-lines have to be compared to the theoretical line which can be drawn using Eq. 1. Our expectations were to get accurately results in case of soil type Nr. 1 because of the accurately calibration of the contact properties of the model. In Fig. 6 it can be seen that the tendency of the trend-lines are similar to the theoretical line.

In case of “wall-type” simulations the line follows closely the theoretical values, the maximum of the relative error in range of 30 N to 300 N vertical loads was 14.04 % (see Tab. 5). In case of “ball-type simulations” this value increased up to 22.44 %. At the other two types of soil model the same conclusion could be said. The most accurate results came in case of soil-type nr. 3 where the maximum relative error was 3.55 %.

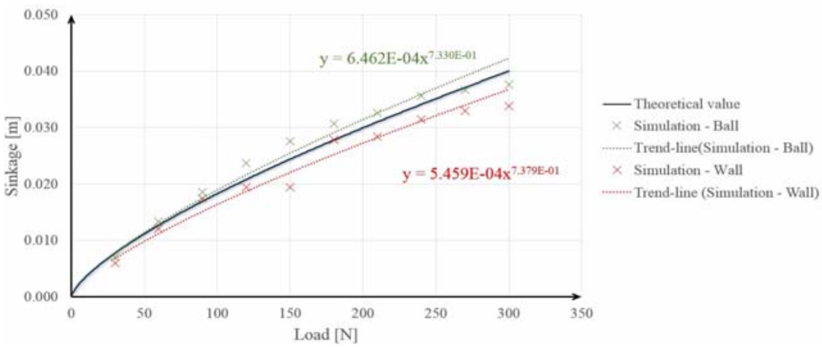


Figure 7. Results of the soil-wheel interaction simulations in case of soil type nr. 2

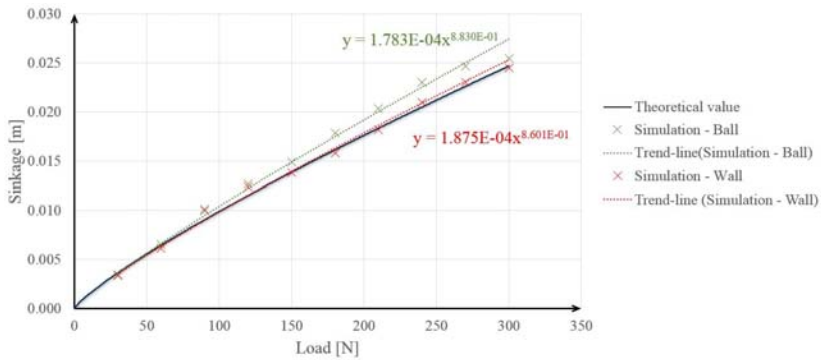


Figure 8. Results of the soil-wheel interaction simulations in case of soil type nr. 3

Table 5. The relative errors of the DEM simulations in range of 30 N to 300 N vertical loads

Description		*Unit*	*Soil type nr. 1.*	*Soil type nr. 2.*	*Soil type nr. 3.*
Relative error in “wall-type” simulations	*Min*	*%*	*3.03*	*8.16*	*0.00*
	Max		*14.04*	*13.03*	*3.55*
Relative error in “ball-type” simulations	*Min*	*%*	*13.01*	*1.25*	*0.07*
	Max		*22.44*	*5.72*	*11.18*

In addition it can be seen as well that the “ball-type” calculations always gave greater sinkage values as results than the “wall-type” simulations. Comparing the calculation times the “wall-type” simulations’ need approximate 1.5 to 2.5 hours to calculate while the “ball-type” simulations had to run approximate 2.5 to 3 hours with the same computing background.

CONCLUSIONS

In this work the soil-rigid wheel interaction was investigated using the discrete element method. In our earlier publications three types of soil model were created, the parallel bond contact parameters were calibrated to the soil's mechanical properties. Using these soil models a tire was pressed into the soil with 10 different vertical loads and the sinkages of the wheel were determined.

In the numerical simulations first the tire was modeled as a rigid wall, after that as a rigid particle. Comparing the two simulation methods, the results show that the sinkage values from the "wall-type" calculations were less than in case of "ball-type" simulations in case of each soil model. In addition, if the calibration of the contact parameters is corresponding, the "wall-type" simulations gave more accurate results than the other. The wheel's sinkage values follow the theoretical values closely. The theoretical sinkages of the wheel were determined using the Bekker-formula. The maximum of the relative error was under 15 %.

Finally the time-consumptions of the two methods were compared to each other. The results show that the "wall-type" simulations needed less computing time than the "ball-type" simulations.

BIBLIOGRAPHY

[1] McKyes, E. 1985. *Soil Cutting and Tillage.* New York: Elsevier.

[2] Sitkei, Gy. 1967. *A mezőgazdasági gépek talajmechanikai problémái.* Budapest: Akadémiai Kiadó.

[3] Cundall, P.A., Strack, O.D.L. 1979. Discrete numerical model for granular assemblies. *Geotechnique,* 29(1), 47-65.

[4] Sadek, M.A., Chen, Y., Liu, J. 2011. Simulating shear behavior of a sandy soil under different soil conditions. *Journal of Terramechanics,* 48, 451-158.

[5] Zhang, R., Li, J. 2006. Simulation on mechanical behavior of cohesive soil by Distinct Element Method. *Journal of Terramechanics,* 43, 303-316.

[6] Tamás, K., Jóri J.I. 2012. 3D discrete element model to describe the draft force and the influences of the tool geometry. *Agricultural Engineering*, 1-2012, 21-34.

[7] Potyondy, D.O., Cundall, P.A. 2004. A bonded-particle model for rock. *International Journal of Rock Mechanics & Mining Sciences,* 41, 1329-1364.

[8] Kotrocz, K., Kerényi, Gy. 2013. Investigation of soil-rigid wheel contact under three different circumstances using discrete element method. *Synergy & Technical Development: III. International Conference of CIGR Hungarian National Committee and Szent István University*, Gödöllő: Section III., N03-1-126.

[9] Bekker, M.G. 1960. Off the road locomotion: research and development in terramechanics. *Univ. of Michigan Press*, Ann Arbor.

[10] Otico agronomic wheels & rollers, 2013, Available through: http://www.otico.com/en/solid_rubber_wheels/complete_wheels_for_conventional_seeders/smooth_wheels_with_convex_dome_shape_62.htm [2013.12.01]

[11] Itasca Consulting Group Inc. 2008. PFC2D Particle Flow Code in 2 Dimensions User's Guide. Minneapolis.

MODELIRANJE INTERAKCIJE ZEMLJE I KRUTOG TOČKA METODOM DISKRETNIH ELEMENATA

Krisztián Kotrocz, György Kerényi

Univerzitet tehnologije i ekonomije u Budimpešti, Mašinski fakultet, Institut za mašinske i proizvodne konstrukcije, Mađarska

Sažetak: U ovom radu je je analizirana interakcija zemlje i krutog točka metodom diskretnih elemenata (DEM). Pripremljena su tri tipa zemljišta sa različitim mehaničkim osobinama. Posle toga, kruti točak je simuliran na dva različita načina: u prvom slučaju kao kruti zid, a zatim kao kruta čestica. U svakom proračunu mereno je propadanje točka pod različitim vertikalnim opterećenjima. Rezultati simulacija su poređeni sa teorijskim vrednostima. Za određivanje teorijskih vrednosti propadanja korišćena je Bekerova jednačina. Na kraju su međusobno poređene tačnost i vreme proračuna dva metoda simulacije.

Ključne reči: *DEM, zemljište, točak, propadanje, Bekerova jednačina*

Prijavljen: *Submitted*:	21.01.2014.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	12.07.2014.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 13 – 19

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 13 – 19

UDK: 631.44

Originalni naučni rad
Original scientific paper

PREPARATION OF SOIL MAP USING REMOTE SENSING AND GIS TECHNOLOGY

Ashwini Patwardhan[1*], Bhau Gavit[2]

[1] *K. K. Wagh College of Agricultural Engineering, Nashik. Affiliated to Mahatma Phule Krishi Vidyapeeth, Department of Irrigation and Drainage Engineering, Rahuri, India*
[2] *Dr. A. S. College of Agril.Engg, Department of Soil and Water Conservation Engineering, Rahuri, India*

Abstract: For efficient utilization of soil and water resources, reconnaissance survey of watershed Godavari valley-5 (GV-5) was carried out in Nashik Soil Survey unit No. 2 for providing comprehensive information characteristics. Representative soil samples from each of eight villages of the sub-catchments of Gangapur were collected. From the record of the area sampled, a sample sketch map for reference was made with the help of magnetic needle. Simultaneously, GPS data was recorded for transferring these points on map/satellite image. The soil samples were tested in laboratory for determining various soil properties viz. soil color, mechanical analysis, liquid limit, plastic limit, soil ph, soil electrical conductivity, soil organic carbon, available nitrogen, available phosphorus, available potassium & soil calcium content. Vector map was prepared from revenue boundary of village under the guidance of MERI, Nashik. From the results obtained from the analysis of vector map, a soil map & land use land cover map was prepared using ERDAS Imagine 8.7 software.

Key words: *GPS, vector, soil, land use land cover map, ERDAS Imagine 8.7 software.*

INTRODUCTION

Agriculture is the backbone of the Indian economy, hence to strengthen the economy agricultural activities should be more productive and precise. More production

[*] Corresponding author. E-mail: satputeaa@yahoo.co.in

can be achieved, if soil and water are efficiently used. For efficient utilization of these resources, detailed map of soil with all sub-unit is essential for the management purposes.

Soil survey is a study and mapping of soil in its natural environment. It is the systematic examination, description, classification and mapping of an area. It is one of the best tools for the management of soil resource. Laboratory analysis by testing of soil for various properties is carried out to support and supplement the field observations. Mapping of soils is done for establishing and drawing soil boundaries of different kinds of soil on standard topographical base map. Survey reports make predictions about the potential of soil for alternative uses like agricultural crop, grasses, fruit forestry or potential crops and ascertaining their management requirement for sustained production. The reconnaissance survey was undertaken to prepare resources inventory of large areas. It identifies kinds of soils and their extent of distribution.

Remote sensing is the science of acquiring information about the earth's surface without being in physical contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing and applying that information. It is the process that involves an interaction between incident radiation and the target of interest.

GIS is a collection of computer hardware, software, and geographic data and display all forms of geographically referenced information. A geographic data is data about land and water resource and human activities.

Vector map is characterized by use of point, line and polygon. Vertices are use to define line segment. Point features are defined by one coordinate pair, a vertex while a polygon features by a set of closed coordinate pairs.

Land use reefer's to man's activity and various uses which are carried on the land, whereas land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and other resulting due to land formations.

GPS (Global Positioning System) is a satellite navigation system designed to provide instantaneous position, velocity and time information almost anywhere on the globe at any time and in any weather condition. GPS gives the longitude, latitude and altitude of particular point on the earth surface. A standard soil map is a two-dimensional presentation on paper gives attribute as well as spatial information.

Appropriate scale soil maps and research data are required to develop interpretation at capability or irritability unit level, particularly to determine the suitability of area for irrigated cropping and long range behavior of soil under irrigation. Hence present study was undertaken to prepare detail soil map in GIS environment and to prepare the land use land cover map using Remote Sensing data.

MATERIAL AND METHODS

Reconnaissance survey of watershed Godavari valley-5 (GV-5) was carried out in Nashik Soil Survey unit No. II (sub-catchment of Gangapur) for providing comprehensive information characteristics. Representative soil samples from each of eight villages viz Anjanneri, Kachurli, Khambale, Metghar Killa, Pimpled Trimbak, Sapgoan, Talwade Trimbak & Trimbakeshwar were collected in Feb 2008. Single representative soil sample were collected from each village except Khambale, as this village had red alluvial soil and black soil in equal proportion. The samples from the soil surface to plough depth 0-22 cm weighing approximately 6 kg were collected. Then the information sheet label was placed inside the gunny bag and then sewing of bag was carried out. From the record of the area sampled, a sample sketch map for reference was made with the help of magnetic needle. Simultaneously GPS reading were also taken for transferring these points on map/satellite image. The soil samples were tested in laboratory for determining various soil properties viz. soil colour, mechanical analysis, liquid limit, plastic limit, soil ph, soil electrical conductivity, soil organic carbon, available nitrogen, available phosphorus, available potassium and soil calcium content using standard methods. [2] [8] Village boundaries were digitized, demarked and traced on toposheet having scale 1:50,000. Toposheet was scanned from vector map and georeferenced with original toposheet. Using ERDAS 8.7 software, image analysis was carried out. Then using GPS latitude, longitude and altitude were defined and demarked on vector map.

For preparation of land use land cover map the IRS (Indian remote Sensing Satellite) P6 software was used [1], which had resolution of about 24m x 24m and image size about 148 km x 148 km. This false colour composite (FCC) image was procured by National Remote Sensing Agency (NRSA), Hyderabad. This raw image was georeferenced with already georeferenced image and with this image, the required image was selected by taking the subset of whole image using ERDAS software. Then image classification was done by supervise classification. By using reconnaissance survey, the classes of barren land, hills and vegetation were demarked.

By using the results of mechanical and chemical analysis, the soil map was prepared in GIS environment.

RESULTS AND DISCUSSION

Different soil properties of eight villages were determined and are shown in Tab. 1.

Table 1. Different soil properties of eight villages

Sr. No	**Village**	**Soil type**	**Soil pH**	**Soil EC ($dS \cdot m^{-1}$)**	**Soil Organic Carbon Content (%)**	**Soil Calcium Carbonate Content (%)**	**Soil Nitrogen Content ($Kg \cdot ha^{-1}$)**	**Soil Phosphorus Content ($Kg \cdot ha^{-1}$)**	**Soil Potassium Content ($Kg \cdot ha^{-1}$)**
1	*Anjanneri*	*Loam*	*5.90*	*0.888*	*1.260*	*7.4*	*664.76*	*406.00*	*616.0*
2	*Kachurli*	*Silty Clay*	*6.27*	*0.108*	*0.461*	*5.6*	*212.46*	*23.54*	*112.0*
3	*Khambale pit-1*	*Clay*	*6.00*	*0.312*	*2.420*	*5.0*	*1310.00*	*35.32*	*548.8*
4	*Khambale pit-2*	*Silty Clay*	*5.86*	*0.232*	*1.150*	*4.7*	*600.00*	*25.50*	*358.4*
5	*Metghar Killa*	*Sand*	*6.41*	*0.101*	*0.920*	*5.8*	*470.00*	*29.43*	*246.5*
6	*Pimpled Trimbak*	*Clay*	*4.98*	*0.229*	*0.346*	*4.8*	*147.84*	*18.81*	*123.2*
7	*Sapgoan*	*Sandy loam*	*6.27*	*0.251*	*2.420*	*5.6*	*1310.00*	*343.39*	*817.6*
8	*Talwade Trimbak*	*Sandy loam*	*6.05*	*0.616*	*0.807*	*7.5*	*406.30*	*74.56*	*313.6*
9	*Trimbakeshwar*	*Clay loam*	*6.87*	*0.231*	*1.150*	*6.5*	*600.15*	*276.67*	*712.8*

The soil pH for eight villages ranged from 4.98 to 6.87. The electrical conductivity of soil was found to be normal, ranging from 0.101 to 0.888 $dS{\cdot}m^{-1}$. The organic content of soil was found to be high in all eight villages and it ranged from 0.346 to 2.42 %. The nitrogen content of soil ranged from 147.84 to1310.0 $kg{\cdot}ha^{-1}$, the phosphorus content ranged from 18.81 to 406 $kg{\cdot}ha^{-1}$ and the potassium content ranged from 112.0 to 817.6 $kg{\cdot}ha^{-1}$. The calcium carbonate content of soil was found to be normal or sufficient, which ranged from 4.7 to 7.5 %.

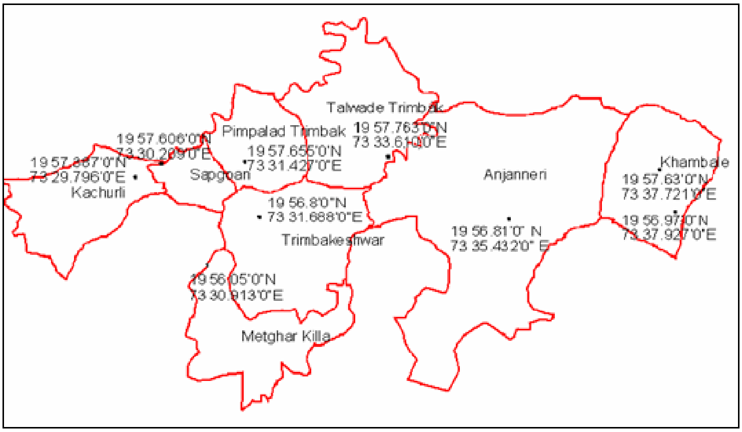


Figure 1. Vector Map of Ganagapur Sub-catchment

Vector map was prepared, which showed the marked boundary of eight villages of GV-5 along with latitude, longitude & position as shown in the Fig. 1.

Then the Satellite imagery for the selected catchment was prepared, which showed 95 to 58 paths and rows as shown in the Fig. 2.

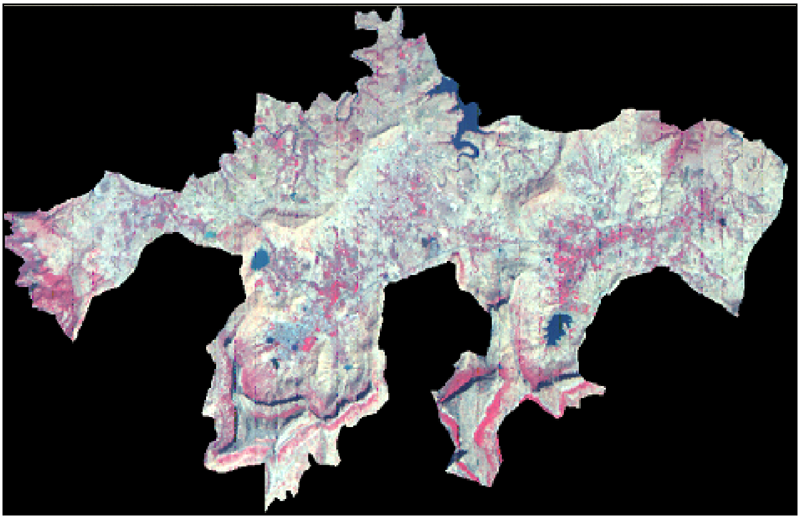


Figure 2. Satellite image of Gangapur Sub-catchment

Land Use Land Cover Map was prepared, showing the supervised classified image with different types of classes such as water bodies, barrier land, fallow land, green vegetation etc. as shown in the Fig. 3.

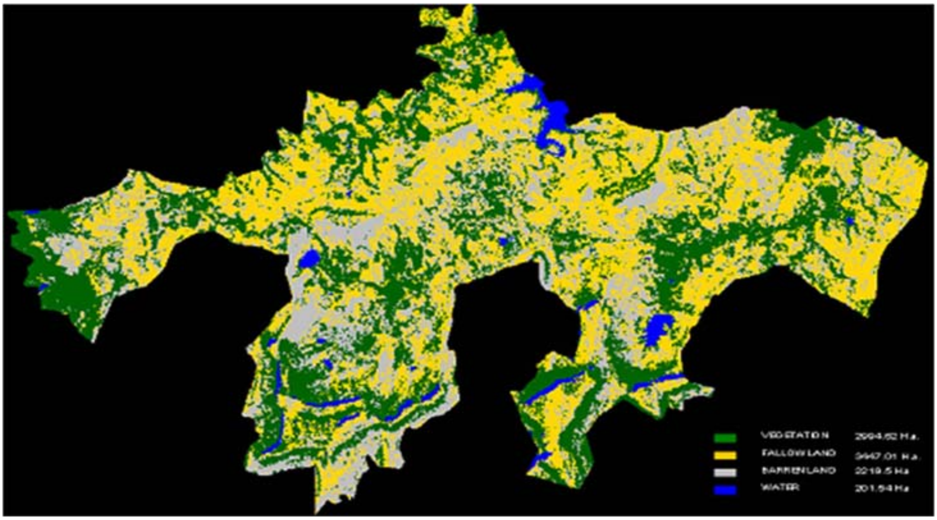


Figure 3. Supervised Classified Land Use/Land Cover image of Gangapur Sub-catchment

Finally, Soil Map showing different types of soil in different colour was prepared, as shown in the Fig. 4.

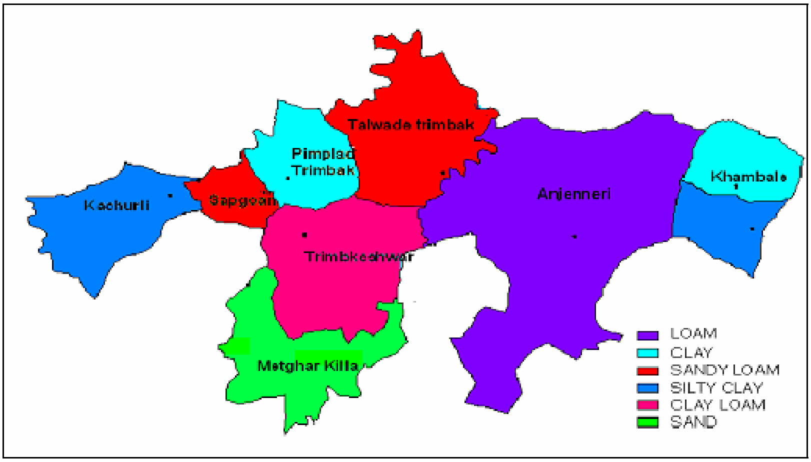


Figure 4. Soil Map of Ganagapur Sub-catchment

It was revealed that from the satellite imagery, one can ascertain the different types of soil classes and determine their acreage, so that planning for different crops can be done [3] [4] [5] [6] [7]. By overlapping the soil map and classified image one can draw conclusion about soil type and vegetation pattern.

CONCLUSIONS

From the present study it was concluded that the soil maps are helpful for farmers in deciding cropping pattern, developing land use plans, demarcating agriculture, forestry and degraded land, allocating land for residential use, roads, parks, waste disposal etc. They are also used for watershed development, in understanding the kinds of the soil for recommending various management practices, to conserve soil and water resources and ensuring their rational use. At Agriculture research stations, soil maps are useful in selecting representative soils for conducting field trial before transferring agro technology to other areas having comparable soil site characteristics and at the research laboratories, in selecting representative pedons for their detailed investigation.

BIBLIOGRAPHY

[1] Cihlar, J. 2000. Land cover mapping of large areas from satellites: status and research priorities. *International Journal of Remote Sensing,* 21(6-7):1093-1114.

[2] Dhyan, Singh, P.K., Chhonkar, R.N. Pandey. 1995. *Soil water analysis a method*. p. 56-63**.**

[3] Dadhwal, V.K., Singh, R.P, Dutta, S., Parihar, J.S. 2002. Remote sensing based crop discrimination and area estimation: A review of Indian experience. *Tropical Ecology*, 43: 107-122.

[4] Dadhwal, V.K, 1999. Remote sensing and GIS for agricultural crop acreage and yield estimation, pp. 58-67. *International Archives of Photogrammetry and Remote Sensing*, XXXII, 7-W9, (ISPRS Commission VII/ WG 2 Symposium on Application of Remote Sensing and GIS for Sustainable Development), March 11, Dehradun, India.

[5] Dadhwal, V.K., Ray, S.S. 2000. Crop Assessment using remote sensing-PartII: Crop condition and yield assessment, *Indian Journal of Agricultural Economics*, 55(2, Supplement):55-67.

[6] Navalgund, R.R., Parihar, J.S, Ajai, Nageshwar, Rao, P.P. 1991. Crop inventory using remotely sensed data. *Current Science*, 61:162-171.

[7] Navalgund, R.R., Ray, S.S. 2000. Geomatics in natural resources management, in *Proceedings of Geomatics*-2000, Pune, India, NR1-NR14.

[8] Punmia, B.C. 2005. *Soil mechanics and foundation*. Laxmi Publication, New Delhi. p. 114-119.

[9] Rajan, Y.S. 2005. *Description and classification of land use and land cover*. Narosa publishing house. New Delhi, fifth edition. p. 54-79.

PRIPREMA ZEMLJIŠNE MAPE KORIŠĆENJEM TEHNOLOGIJE DALJINSKE DETEKCIJE I GIS

Ashwini Patwardhan[1], Bhau Gavit[2]

[1] *K. K. Wagh Fakultet za poljoprivrednu tehniku, Nashik, Institut za navodnjavanje i odvodnjavanje, Rahuri, India*
[2] *Dr. A. S. Fakultet za poljoprivrednu tehniku, Institut za konzervaciju zemljišta i vode, Rahuri, India*

Sažetak: Za efikasnu upotrebu zemljišnih i vodenih resursa izvedeno je prethodno ispitivanje rečnog sliva Godavari doline-5 (GV-5) u Nashik pregledu zemljišta, čime su dobijene opsežne informacije o karakteristikama. Sakupljeni su reprezentativni uzorci zemljišta iz svakog od osam sela područja Gangapur. Iz podataka o uzorkovanoj oblasti napravljena je referentna mapa uzoraka. Istovremeno, GPS podaci su memorisani radi transfera ovih tačaka na mapu/satelitski snimak. Uzorci zemljišta su testirani u laboratoriji radi određivanja različitih zemljišnih karakteristika: boja, mehanička analiza, granična lažnost, granična plastičnost, kiselost, elektroprovodljivost, organski ugljenik, dostupni azot, dostupni fosfor, dostupni kalijum i sadržaj kalcijuma. Napravljena je vektorska mapa na osnovu katastarskih granica sela pod vođstvom MERI, Nashik. Analiza vektorske mape, zemljišne mape i mape upotrebe i pokrivenosti zemljišta izvedena je upotrebom programa ERDAS Imagine 8.7.

Ključne reči: *GPS, vektor, zemljište, mapa upotrebe i pokrivenosti zemljišta, ERDAS Imagine 8.7 program.*

Prijavljen: *Submitted*:	12.05.2014.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	17.08.2014.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 21 – 29

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 21 – 29

UDK: 321.979

Originalni naučni rad
Original scientific paper

PROCENA RIZIKA PO ZDRAVLJE VOZAČA, OD VIBRACIJA NASTALIH PRI EKSPLOATACIJI TRAKTORA

Boban Cvetanović[1*], Miljan Cvetković[1], Dragan Cvetković[2]

[1] *Univerzitet u Nišu, Visoka tehnička škola strukovnih studija, Niš, Srbija*
[2] *Univerzitet u Nišu, Fakultet zaštite na radu, Niš, Srbija*

Sažetak: Vozači poljoprivrednih traktora izloženi su, tokom rada, mnogobrojnim štetnim faktorima, među kojima se nalaze i vibracije. U pitanju su opšte vibracije koje nastaju u motoru, pri radu traktora, i prenose se, preko sedišta, poda i komandi vozila do celog tela vozača (whole body vibration). Izloženost ovim vibracijama, u dužem periodu, može dovesti do ozbiljnih zdravstvenih problema vozača. Zato je procena rizika po zdravlje od vibracija, kod profesionalnih vozača traktora, izuzetno bitna sa aspekta razvijanja zaštitnih mehanizama. Iako uobičajena procedura procene rizika podrazumeva proučavanje svih opasnosti i štetnosti koje se mogu pojaviti na određenom radnom mestu, u radu je urađena samo procena rizika po zdravlje vozača traktora od štetnog delovanja vibracija. Za ovu procenu korišćen je matrični model 5x5, pri čemu je procena pokazala da vozači i rukovaoci teškom mehanizacijom rade u uslovima povećanog rizika od vibracija. Iz tog razloga dato je nekoliko organizacionih i tehničkih mera koje je poslodavac dužan da preduzme kako bi se povećani rizik smanjio ili potpuno redukovao.

Ključne reči: *procena rizika, vibracije, poljoprivredni traktori*

UVOD

Traktori, kao jedno od najčešćih sredstava poljoprivredne mehanizacije, značajno su uticali na ogromno povećanje proizvodnosti i efikasnosti poljoprivrednih radova i direktno olakšanje, a negde i potpuno eliminisanje fizičkog rada poljoprivrednih radnika.

[*] Corresponding author. E-mail: boban.cvetanovic@vtsnis.edu.rs

TEMPUS JPHES 158781 Occupational safety and health - degree curricula and lifelong learning Finansiran od Evropske unije, u periodu od 2010. do 2013.godine.

Sa druge strane, tokom svojih svakodnevnih radnih aktivnosti, vozači traktora, izloženi su mnogobrojnim nepovoljnim uticajima koji imaju kompleksno štetno dejstvo na zdravlje čoveka i efikasno obavljanje radnih zadataka. Pored fizičkog naprezanja, buke, atmosferskih padavina, velike vlažnosti, visokih ili niskih temperatura, prašine i različitih hemijskih zagađenja, kao jedna od značajnih štetnosti pojavljuju se i vibracije [1-3, 11].

U pitanju su vibracije uzrokovane radom pogonskog motora traktora, kao i radnim procesima priključnih oruđa i agregata, a u sadejstvu sa neravninama tla. Naime, celo vozilo, u radnim uslovima, izloženo je složenim oscilatornim procesima koji se od motora, preko transmisije i šasije, prenose do kabine i dalje preko poda, sedišta i radnih komandi do tela vozača.

Pojedine studije ukazuju da je oko 10% svih vozača traktora, tokom osmočasovnog radnog vremena, izloženo nivoima iznad dnevne granične vrednosti izloženosti (*eng. Exposure limit value-ELV*), dok u slučaju dužeg radnog dana taj procenat raste na 27%. Čak 95% svih vozača traktora tokom radnog dana od 8 časova izloženo je nivoima iznad dnevne upozoravajuće vrednost izloženosti (*eng.exposure action value-EAV*) kada su poslodavci dužni kontrolisati rizike proizašle iz vibracija [1,11].

Dejstva vibracija na zdravlje čoveka su brojna, ali se, često, zbog udruženosti vibracija sa drugim profesionalnim opasnostima i štetnostima, ne može, potpuno jasno, uspostaviti uzročno-posledična veza između dejstva vibracija i oštećenja zdravlja. Ipak, brojne studije i istraživanja, pokazuju da kraća, ali konstantna, izloženost visokim vrednostima vibracijama, može izazvati bol u stomaku i grudima, nedostatak daha, mučninu, i vrtoglavicu, dok dugotrajna i konstantna izloženost može dovesti do poremećaja psihomotornog, fiziološkog i psihološkog sistema radnika [4-7].

Prema podacima iz 2012 [12], u Republici Srbiji ima 410.894 dvoosovinska traktora, od kojih je u poljoprivrednoj godini 2011/2012. korišćeno 98,4% (404.512). Pri tome je 398.829 ili 98,6% traktora, prema pravnom statusu, pripadalo porodičnim gazdinstvima Ovo znači da, u odnosu na broj traktora, imamo veoma mali broj profesionalnih vozača traktora, dok sa druge strane, postoji ogroman broj samostalnih poljoprivrednih proizvođača, koji su, kao vozači traktora na svojim porodičnim gazdinstvima, izloženi visokim vrednostima vibracija, vrlo često preko dozvoljenih granica, o čemu ne postoji precizna evidencija i statistika. Drugim rečima, u poljoprivrednoj proizvodnji Republike Srbije, postoji ugrožena radna grupa u pogledu štetnog dejstva vibracija, iako ona nije profesionalno angažovana u pravom smislu te reči.

Štetno dejstvo vibracija naročito je izraženo kod starijih traktora kod kojih ne postoji efikasan sistem amortizovanja vibracija i udaraca jer su pravljeni sa prostim vešanjem na prednjoj osovini i prostim mehaničkim sedištima [8]. Starosna struktura traktora u Republici Srbiji je nepovoljna i prelazi 10 godina na društveno-državnom i 15 godina na privatnom sektoru [13].

Postupkom procene rizika za radno mesto vozača, može se ukazati na nivo bezbednosti svih poljoprivrednih proizvođača koji upravljaju traktorom, bez obzira da li oni rade na porodičnim gazdinstvima ili su radnici – vozači traktora zapošljeni na poljoprivrednim gazdinstvima. Iako standardna procena rizika podrazumeva analizu svih opasnosti i štetnosti koje se mogu pojaviti na radnom mestu, u ovom radu će se dati samo procena rizika od vibracija kao jedne od najuticajnijih štetnosti na zdravlje vozača traktora. Prikazaće se najvažniji koraci koji moraju biti preduzeti, kako bi se utvrdile štetnosti po zdravlje, uzrokovane vibracijama. Nakon toga izvršiće se procena stvarnog rizika po zdravlje, korišćenjem matričnog modela 5x5. Na osnovu podataka, dobijenih nakon procene, moguće je razvijati zaštitne mehanizme (tehničke i organizacione) kojima se smanjuju negativni efekti vibracija. Na kraju rada ukazaće se na neke od mera koje se mogu preduzeti u cilju smanjenja nivoa vibracija kod traktora.

MATERIJAL I METODE RADA

Procenom rizika moguće je, u ranoj fazi, prepoznati i smanjiti izloženost, odnosno preventivno delovati.

Univerzalna ili konkretna metoda za procenu rizika nije propisana zakonskom ili normativnom regulativom. Praktično od licencirane ustanove i samog procenjivača rizika zavisi koja će metoda procene rizika biti izabrana. Ipak, primena nedovoljno poznatih ili neproverenih metoda procene ili, još gore, improvizacija procene rizika uzrokuje veoma ozbiljne greške u mnogim segmentima procene, sa mogućim ozbiljnim posledicama po zdravlje i bezbednost zaposlenih [5].

U konkretnom slučaju treba voditi računa da rizik kojem je vozač traktora izložen zavisi od intenziteta i frekvencija vibracija, kao i od trajanja izloženosti i načina rada. Važno je znati da osećaj pojedinca pri izlaganju vibracijama (subjektivni osećaj), zavisi od zdravstvenog stanja i vrsti aktivnosti koja se izvodi. Razumevanje načina na koji su vozači izloženi vibracijama pomoći će usvajanju metoda za smanjenje ili potpuno uklanjanje izloženosti. Rizik radnog mesta može se proceniti u 3 jednostavna koraka:

1. Prikupljanje informacija i identifikacija rizika
2. Procena i vrednovanje rizika
3. Aktivnosti na eliminisanju ili smanjivanju rizika

Početak procesa je prikupljanje realnih informacija o radnom mestu i prepoznavanje štetnosti. Nakon toga prelazi se na samu procenu rizika nekom od metoda kojom je moguće izvršiti ocenu i upravljanje rizicima. Preduzimanje aktivnosti za smanjenje rizika čini se u samo u slučaju da procena ukaže na povećani rizik.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Prikupljanje informacija i identifikacija štetnosti od vibracija

Za procenu rizika mesta rada potrebno je prikupiti veći broj informacija o tome gde se nalazi radon mesto i ko tamo radi, koja oprema i materijali se koriste pri radu, koji zadaci se obavljaju, koje se zaštitne mere već koriste itd. Informacije se prikupljaju u tehničkim podacima koje je proizvođač dao o opremi, priručnicima za rad i katalozima, iz pravnih propisa i tehničkih normi itd. Proizvođači opreme i mašina su u obavezi da osiguraju podatke o vibracijama koje stvara oprema i to u obliku rezultata merenja u uslovima ispitivanja.

Jedna od najmerodavnijih informacija o štetnosti vibracija na vozača traktora dobija se odgovarajućim merenjima tokom radnih aktivnosti. Neposredno merenje sile koja stvara vibracije je teško ostvarivo, pa se prilikom sprovođenja analize vrši merenje odziva sistema (posledica) na dejstvo sile, a to su vibracije. Vibracije koje se, preko sedišta, prenose na telo rukovaoca mogu se definisati u vidu: pomeranja, brzine i ubrzanja vibracija. Ukoliko se ne zahteva merenje posebnog parametara, npr. zbog zahteva nekog standarda, opšte je pravilo da treba izabrati parametar koji ima najravniji odziv u posmatranom frekvencijskom opsegu. Pri merenju veličina vibracija kod vozača i operatera na mašinama i vozilima, kao parametar za merenje i ocenu, uzima se ubrzanje (akceleracija). Merenja intenziteta vibracija se vrše na sedištu vozača ili podu vozila. Merenja zahtevaju odgovarajuću opremu i obavljaju se po određenoj, propisanoj metodologiji. Na osnovu izmerenih vrednosti utvrđuje se nivo dnevne izloženosti, A(8) – kontinuirana ekvivalentna akceleracija, normirana s obzirom na 8-satno radno vreme ili vrednost vibracijske doze (*eng. Vibration dose value – VDV*), koja predstavlja kumulativnu dozu. U slučaju dnevne izloženosti vibracijama koje se prenose na celo telo, u Directive 2002/44/EC, navedene su dnevna granična vrednost izloženosti (ELV) koja ne sme biti prekoračena u profesionalnim uslovima i iznosi 1,15m/s2, te dnevna upozoravajuća vrednost izloženosti (EAV) iznad koje su poslodavci dužni kontrolisati rizike proizašle iz vibracija i iznosi 0,5m/s2 [9]. Nacionalne regulative mogu imati i strože zahteve.

Procena i vrednovanje štetnosti od vibracija

Jedna od metoda kojom je moguće izvršiti ocenu i upravljanje rizicima je matrični model 5x5. Ova metoda rizik i izražava kao proizvod verovatnoće nastanka povrede na radu, oštećenja zdravlja i oboljenja u vezi sa radom (V) i posledica težine povrede, oštećenja zdravlja i oboljenja u vezi sa radom (T):

$$R = V \times T \qquad (1)$$

Verovatnoća nastajanja povreda, oštećenja zdravlja i oboljenja u vezi sa radom, stvar je subjektivnog izbora procenjivača rizika. Ocena verovatnoće vrši se na osnovu informacija do kojih je procenjivač došao merenjima vibracija i izračunavanjem nivoa izloženosti kod većeg broja vozila ili korišćenjem takvih podataka iz literature, kataloga, tehničkih priručnika i sl. Takođe su važni i podaci o broju profesionalnih bolesti i oštećenja zdravlja kao posledica dejstva vibracija.

U slučaju vozača poljoprivrednog traktora, procena je vršena korišćenjem rezultata merenja nivoa izloženosti vozača, u realnim radnim uslovima, na različitim traktorima. Deo rezultata je iz dostupnih inostranih studija koje se bave ovom problematikom, a deo je plod sopstvenih merenja vibracija na domaćim IMT traktorima. Poseban problem pri određivanju opšte procene i davanju opšteg suda, predstavlja podatak da su kod novijih traktora i naročito traktora renomiranih inostranih proizvođača, vrednosti izmerenih vibracija mnogo manje nego u slučaju starih traktora domaćeg proizvođača traktora IMT [1,2,5,10].

U slučaju 8-časovnog radnog vremena, procena je da postoji srednja verovatnoća nastajanja oštećenja zdravlja – C (Tab. 1) i srednje posledice po zdravlje vozača - III (Tab. 2). Izbor srednje verovatnoće oštećenja zdravlja i srednje teškog oboljenja u vezi sa radom u slučaju vozača traktora, posledica je mnogobrojnijih naučnih studija i istraživanja iz ove oblasti. Prvi simptomi oštećenja zdravlja javljaju se tek posle 5 godina konstantnog izlaganja visokim nivoima vibracija, a kao posledica se javljaju raznoliki poremećaji zdravstvenog stanja.

Tabela 1. Stepenovanje verovatnoće nastanka povrede na radu ili bolesti u vezi sa radom (V)

Table 1. Grading the probability of occurrence of occupational injury or illness related to work (V)

Verovatnoća nastanka povrede na radu, oštećenja zdravlja i oboljenja u vezi sa radom (V) *Probability of injury, damage to health and disease related to work (V)*		Opis *Description*
Vrlo mala ili zanemarljiva *Very small or negligible*	*A*	Može se dogoditi u izuzetnom slučaju (verovatno ni jednom u toku postojanja firme) *It can happen in exceptional cases (probably once during the existence of the company)*
Mala *Small*	*B*	Može se dogoditi jednom u periodu od 10 i više godina *It may happen once in a period of 10 years or more*
Srednja *Medium*	*C*	Može se dogoditi jednom u periodu od 1 do 10 godina (retko u normalnim okolnostima) *It may happen once in a period of 1 to 10 years (rare in normal circumstances)*
Velika *Big*	*D*	Očekuje se da će se desiti jednom u toku godine *Expected to occur once a year*
Izrazito velika *Extremely big*	*E*	Očekuje se da će se desiti više puta godišnje (gotovo sigurno) *Expected to occur several times a year (almost certainly)*

Tabela 2. Ocena težine mogućih posledica povrede na radu ili bolesti u vezi sa radom (T)

Table 2. Evaluation of possible consequences of occupational injury or illness related to work (T)

Posledica težine povrede na radu ili bolesti u vezi sa radom (T) *Consequence severity of occupational injury or illness related to work (T)*		Opis *Description*
Vrlo laka povreda na radu/oboljenje u vezi sa radom ***Very easy** work injuries/illnesses related to work*	*I*	Potrebna je samo prva pomoć, beznačajno oštećenje organa, očuvana funkcija, nema opasnosti od daljih zdravstvenih komplikacija, očuvana radna sposobnost. *You only need first aid, insignificant damage to organs, preserved function, there is no risk of further health complications, preserved ability to work.*
Laka povreda na radu/oboljenje u vezi sa radom ***Easy** occupational injuries /illnesses related to work*	*II*	Potrebna je intervencija medicinskog osoblja, lako oštećenje organa, privremeno oštećenje funkcija, ne očekuju se dalje zdravstvene komplikacije, očekuje se kratkotrajna privremena radna nesposobnost (posekotine, nagnječenja, dermatiti). *Require the intervention of the medical staff, easy organ damage, temporary impairment of function, is not expected to further health complications, expected short-term temporary work incapacity (cuts, bruises, dermatitis.).*
Srednje teška povreda na radu/ oboljenje u vezi sa radom	*III*	Potrebno je bolničko lečenje, značajna oštećenja organa, abiatno ali privremeno izmenjena funkcija, moguća opasnost od daljih zdravstvenih komplikacija, očekuje se duža radna nesposobnost i moguća trajna izmena radne sposobnosti (veće frakture, nagnječenja, iščašenja i sl.)

***Moderate** injuries at work/illness related to work*		*You need hospitalization, significant organ damage, abiat but temporarily changed function, the possible risk of further health complications, expected longer work disability and possible permanent changes of working capacity (larger fractures, contusions, sprains, etc.).*
Teška povreda na radu/oboljenje u vezi sa radom ***Severe** occupational injuries/illnesses related to work*	*IV*	Moguća trajna nesposobnost/invalidnost, trajno značajno oštećenje ili uništenje organa sa mogućim smrtnim ishodom (amputacije, višestruke povrede, oboljenja u vezi sa radom koja dovode do invalidnosti) *Possible permanent disability/disability, permanent significant damage or destruction of organs with possible fatal outcome (amputation, multiple injuries, illnesses related to work that lead to disability)*
Kolektivna povreda na radu ili povrede na radu sa smrtnim ishodom ***The collective** work injuries or occupational injuries resulting in death*	*V*	Moguće teške povrede na radu i oboljenja u vezi sa radom većeg broja ljudi u istom periodu vremena *Possible serious injuries and illnesses related to the work of a number of people in the same period of time*

Nakon usvajanja brojnih vrednosti iz Tab. 1 i 2, može se sračunati rizik. U slučaju vozača poljoprivrednog traktora klasifikovan je srednji rizik od dejstva vibracija koje se prenose na telo vozača (Tab. 3).

Tabela 3. Ocena nivoa rizika

Table 3. Assessment of the level of risk

Verovatnoća nastanka povrede na radu ili bolesti u vezi sa radom (V) *Probability of occupational injury or illness related to work (V)*		Težina mogućih posledica povrede na radu ili bolesti u vezi sa radom(T) *Weight of the possible consequences of occupational injury or illness related to work (T)*				
		Vrlo laka *Very easy*	Laka *Easy*	Srednje teška *Moderate*	Teška *Severe*	Kolektivna *Collective*
		I	*II*	*III*	*IV*	*V*
Vrlo mala ili zanemarljiva *Very small or negligible*	*A*	Zanemarljiv *Negligible*	Zanemarljiv *Negligible*	Mali *Small*	Mali *Small*	Mali *Small*
Mala *Very small or negligible*	*B*	Zanemarljiv *Negligible*	Mali *Small*	Srednji *Moderate*	Srednji *Moderate*	Veliki *Big*
Umerena *Moderate*	*C*	Mali *Small*	Srednji *Moderate*	Srednji *Moderate*	Srednji *Moderate*	Veliki *Big*
Velika *Big*	*D*	Mali *Small*	Srednji *Moderate*	Veliki *Big*	Veliki *Big*	Izrazito veliki *Extremely big*
Izrazito velika *Extremely big*	*E*	Mali *Small*	Veliki *Big*	Veliki *Big*	Izrazito veliki *Extremely big*	Izrazito veliki *Extremely big*

Klasifikovani srednji rizik ima karakter povećanog rizika tj. rizik za koji postoji opravdana pretpostavka da može izazvati oboljenja u vezi sa radom i uzrokovati kršenje zakonskih obaveza (Tab. 4).

Tabela 4. Klasifikacija i karakterizacija rizika
Table 4. Classification and characterization of risk

Klasifikacija rizika *Risk classification*	Karakterizacija rizika *Risk characterization*
Zanemarljiv *Negligible*	Prihvatljiv *Acceptable*
Mali *Small*	
Srednji *Moderate*	Povećani *Increased*
Veliki *Big*	Neprihvatljiv *Unacceptable*
Izrazito veliki *Extremely big*	

Nakon utvrđivanja postojanja povećanog (ili neprihvatljivog) rizika po zdravlje, neophodno je preduzeti odgovarajuće aktivnosti kako bi se eliminisali ili smanjili vibracija do granica preporučenih ograničenja.

Aktivnosti na eliminaciji ili smanjenju rizika od vibracija celog tela

U slučaju povećanog ili neprihvatljivog rizika, poslodavac je dužan primeniti odgovarajuće korektivne mere kako bi se on smanjio ili potpuno eliminisao. Veliku ulogu u tom procesu igra razumevanje radnih procesa koji uzrokuju vibracije tj. Prepoznavanje načina na koji su radnici izloženi vibracijama. Prilikom preduzimanja korektivnih mera treba postaviti realno dostižne ciljeve, odrediti prioritete, osmisliti program delovanja i odrediti zaduženja. Sve mere mogu se podeliti na tehničke i organizacione.

Najprostija tehnička mera za kontrolu vibracija je pravilno održavanje traktora. Pri tome se, pre svega, misli na propisno održavanje odgovarajućih sistema oscilatorne udobnosti (vešanje, pnumatici, sedišta). Traktori starije generacije nemaju efikasan sistem amortizovanja vibracija i udaraca jer su pravljeni sa prostim vešanjem na prednjoj osovini i prostim mehaničkim sedištima. Čini se da zamena postojećih sedišta, kvalitetnijim sa poluaktivnim ili čak aktivnim ogibljenjem nije prikladno rešenje za većinu poljoprivrednika zbog cene takvih sedišta, naročito u poređenju sa cenom samog traktora, starosti dvadesetak godina. Kao ekonomski isplativije rešenje može biti postavljanje jastuka ispunjenih različitim materijalim i fluidima na sedište, sa ciljem da redukuju ili potpuno eliminišu vibracije, mada ovo rešenje nije još dovoljno ispitano u praksi.

Kada se govori o organizacionim merama, prva je da izloženost vibracijama bude što je moguće kraće, a treba vršiti i češću zamena vozača. Ipak, i ova metoda se može pokazati kao potpuno neefikasna u slučaju naših samostalnih poljoprivrednika, koji nemaju mogućnost zamene ili skraćenja rada na svojim parcelama u vreme izvođenja poljoprivrednih radova. U takvim uslovima, važna mera može biti obuka, informisanje, i savetovanje sa radnicima i njiuhovo učešće u procesu smanjenja rizika. Vozače traktora je važno informisati o oštećenju zdravlja koje može proizaći iz upotrebe opreme sa kojom rade, o graničnim i upozoravajućim vrednostima izloženosti, o rezultatima procene rizika, uslovima u kojima radnici imaju pravo na zdravstveni nadzor itd. Savetovanjem sa radnicima može se doći do boljih i radnicima shvatljivih rešenja jer učinak planiranih mera zavisi od radnika.

ZAKLJUČAK

Štetno delovanje vibracija traktora na vozače traktora je poznato, ali još uvek potcenjeno. Potpuna uzročno – posledična veze između dejstva vibracija i oštećenja zdravlja vozača ne može se uspostaviti zbog udruženosti vibracija sa drugim profesionalnim opasnostima i štetnostima. Izloženost vibracijama može uticati na vozače na različite načine, od običnih smetnji i smanjenja radnog učinka, do ozbiljnih oštećenja zdravlja, a sve u zavisnosti od dužine izlaganja i nivoa samih vibracija.

Kao rezultat procene rizika dobija se povećani rizik po zdravlje vozača traktora, naročito kada su u pitanju traktori starije generacije. Bez obzira da li se radi o profesionalnim vozačima traktora ili samostalnim poljoprivrednim proizvođačima koji upravljaju traktorom, neophodno je da se preduzmu odgovarajuće mere i aktivnosti za redukciju ili potpuno uklanjanje vibracije, pri čemu je izuzetno je važno da u proceni rizika ravnopravno učestvuju tehnička lica i lekari specijalisti medicine rada.

LITERATURA

[1] Scarlett, A.J., Price, J.S., Stayner, R.M. 2007. Whole – body vibration: Evaluation of emission and exposure levels arising from agricultural tractors. *Journal of terramechanics* 44, 65-73.

[2] Prokeš, B., Mačvanin, N., Simikić, M., Savin, L., Lomen, I. 2013. Intenzitet opštih vibracija kod vozača poljoprivrednih traktora pri različitim režimima rada. *Savremena poljoprivredna tehnika* 39(1): 65-76

[3] Prokeš, B., Mačvanin, N., Furman, T. 2010. Vozači-rukovaoci poljoprivrednih mašina-karakteristike bolesti vezanih uz rad. *Savremena poljoprivredna tehnika* 36 (4): 465-472

[4] Futatsuka, M. 1998. Whole-Body Vibration and Health Effects in the Agricultural Machinery Drivers. *Industrial Health.* 36 (1998): 127-132.

[5] Prokeš, B., Mačvanin, N., Savin, L., Simikić, M., Lomen, I. 2012. Mogući zdravstveni efekti vibracija na vozače traktora i mere za njihovu prevenciju. *Savremena poljoprivredna tehnika* 38(3):243-253.

[6] Boshuizen H.C. 1990. Self-Reported Back Pain in Tractor Drivers Exposed to Whole-Body Vibration. *International Archives of Occupational and Environmental Health*. 62: 109-115.

[7] Bovenzi M., Betta A. 1994. Low-Back Disorders in Agricultural Tractor Drivers Exposed to Whole-Body Vibration and Postural Stress. *Applied Ergonomics*. 25: 231-241.

[8] Oude Vrielink, H. 2012. *Comparasion of high-power agricultural tractors: effect on whole-body vibration exposure during a standardized test in practice.* Final report tractor suspension test (Nederland)

[9] *Directive 2002/44/EC of the European parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)* (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).

[10] Cvetanović, B., Đekić, P., Cvetković, M., Perić, D. 2014. Nivoi dnevne izloženosti vibracijama vozača, pri oranju traktorom IMT 539 De Luxe. *Zbornik radova 9. Međunarodnog savetovanja Rizik i bezbednosni inženjering*

[11] Servadio, P., Marsili, A., Belfiore, N.P. 2007. Analysis of driving seat vibrations in high forward speed tractors. *Biosystems engineering* 97: 171-180

[12] *Popis poljoprivrede 2012 – Poljoprivreda u Republici Srbiji,* Republički zavod za statistiku Republike Srbije, 2013.

[13] Nikolić, R. 2013. Motori i traktori-stanje i potrebe, *Traktori i pogonske mašine*, 18 (1): 6-11.

HEALTH RISK ASSESSMENT OF VIBRATION GENERATED BY TRACTOR EXPLOITATION TO THE DRIVERS

Boban Cvetanović[1], Miljan Cvetković[1], Dragan Cvetković[2]

[1] *University of Niš, College of Applied Technical Sciences, Niš, Serbia*
[2] *University of Niš, Faculty of Ocupational Safety, Niš, Serbia*

Abstract: Drivers of agricultural tractors are exposed during operation, a number of harmful effects, such as high or low temperatures, high humidity, dust, noise, etc. Among the adverse factors there are vibrations from the engine, during the operating, and are transmitted through the seat, floor and commands of the vehicle to the driver's entire body. Exposure to high levels of vibration, in the long term, can lead to serious health problems and permanent damage of the driver's health. Therefore, the health risk assessment of vibration for the professional tractor drivers is extremely important in terms of developing of protection mechanisms. Although the usual procedure of risk assessment involves the study of all hazards and harmful effects that may occur in a specific workplace, in this work is done only health risk assessment tractor drivers from the harmful effects of vibration, whereby the assessment used a simple 5x5 matrix method. Evaluation was carried out using the results of measuring the level of exposure to the driver in real operating conditions, on the different tractors. Part of the results is available from international studies dealing with this issue, a part of the result its own vibration measurements on the domestic IMT tractors. The risk assessment showed that drivers and operators of heavy machinery are working in conditions of increased risk of vibration. For this reason, it`s given a number of organizational and technical measures that should be taken by employer to reduce increased risk of or completely reduced risk.

Key words: *risk assessment, vibration, agricultural tractors*

Prijavljen: *Submitted*:	03.03.2014.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	07.09.2014

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 31 – 40

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 31 – 40

UDK: 637.52

Originalni naučni rad
Original scientific paper

FOURIER TRANSFORM NEAR - INFRARED SPECTROSCOPY FOR NONDESTRUCTIVE AND RAPID MEASUREMENT OF MOISTURE CONTENT OF PADDY

Pandiselvam Ravi[1*], Thirupathi Venkatachalam[1], Vennila Palanisamy[2]

[1]Tamil Nadu Agricultural University, Department of Food and Agricultural Process Engineering, Coimbatore. India
[2]Post Harvest Technology Centre, Coimbatore, India

Abstract: The accurate measurement of moisture content of paddy is essential for the effective supervision of its quality. The feasibility of measuring moisture content in paddy was investigated by Fourier Transform Near-Infrared (FT-NIR) spectroscopic technique. A calibration model was developed using paddy standards of varying moisture content in the near-infrared region (4000–12000 cm^{-1}). The developed model was validated. FT-NIR spectroscopy with chemometrics, using the PLS–first derivative plus vector normalization method could predict the moisture content in paddy samples accurately up to an correlation coefficient (R^2) value greater than 0.97, RPD (residual predictive deviation) greater than 6 and root mean square error of cross validation (RMSECV) value less than 0.5 with 5 factors in the prediction model. The developed model was applied to predict moisture content in paddy samples within 10-12 seconds. The developed procedure was further validated by recovery studies by comparing with oven method and indirect method (digital moisture meter) of moisture determination.

Key words: *NIR Spectroscopy, chemometrics, paddy, moisture content, calibration, validation, PLS factor*

INTRODUCTION

Paddy is one of the most important crops grown in India. In storage conditions contrary with the prescribed moisture content occurs deterioration of paddy. Moisture

[*] Corresponding author. E-mail: anbupandi1989@yahoo.co.in

content is the key parameter in paddy it plays a major role in the shelf life and storage time. Indeed, it has been shown that the decrease in the moisture content induces an increase in the shelf-life and a decrease in the spoilage occurrence. When the moisture content increases, water from the process of respiration accumulates and supports further metabolic processes. Generated heat contributes to even more intense respiration and may eventually damage sensory and physiological properties of grain or spontaneous combustion may occur [1].

There are two major methods to determine the moisture content of grains: direct methods and indirect methods. Direct methods, the water content in the kernels are removed totally. However, direct method is tedious, destructive, relatively expensive and time-consuming, as well as they require highly skilled operators [2]. Indirect methods in which electrical conductance and capacitance characteristic of the grain is measured that are affected by moisture content of the grain. These techniques are rapid and easy to use. However, they must be calibrated by standard moisture content that is measured by a direct method. Even though indirect method consume less time as compared to direct method it is less accurate. Rice milling industries, Food Corporation of India, Central Warehousing Corporation and various paddy research stations are suffer during measurement of moisture content in paddy due to time consuming, destructive and less accurate methods.

Near infrared spectroscopy (FT-NIR spectroscopy) is the spectroscopy that deals with the infrared region of the electromagnetic spectrum, which is light with a longer wavelength and lower frequency than visible light. In recent years, NIR spectroscopy has become a valid tool supporting destructive methods. The application of near infrared spectroscopic technique for the quantitative analysis of food products and commodities is nowadays widely accepted. Several studies have been reported on the use of NIR spectroscopy as a rapid and cost-effective analytical tool to determine the food structure and properties in fundamental research and as on-line sensors for monitoring process [3]. The NIR spectrum of an organic material gives a global signature of composition based on the assessment of the organic chemical structures containing O-H, N-H and C-H bonds [4]. Advantages of near infrared spectroscopy include minimal sample preparation (may be performed *in situ* in many instances), rapid analysis and much deeper sample penetration than far or mid infrared radiation [5].

Nevertheless, only few studies have addressed the application of NIR spectroscopy in moisture content studies; [6] used NIR spectroscopy to determine the moisture content in fishmeal and [2] studied the water content of surimi by NIR spectroscopy but none of the researchers determine the composition of paddy by FT-NIR spectroscopy. The aim of this work was to evaluate the feasibility of FT-NIR spectroscopy as a rapid non-destructive approach for moisture content measurement of paddy.

MATERIAL AND METHODS

Raw Material

Paddy was obtained from centre farm, located in Tamil Nadu Agricultural University, Coimbatore of Tamil Nadu, India and used for the study. The paddy was cleaned manually to remove all foreign materials such as dust, dirt, chaff and immature paddy.

Destructive methods of estimation of moisture content in paddy

Direct method / Oven method

As per Association of Official Analytical Chemists [7] standard method, 25-30 g of whole paddy was dried at 130°C for 14-16 h.

Indirect method / Digital moisture meter

Indirect method of moisture measurement was done by using PSAW digital moisture meter. The operation of PSAW digital moisture meter is based on the fact that the electrical conductivity of a moist material is directly proportional to the amount of moisture contained in it. Electrical conductivity also varies with the temperature. A built in temperature sensor along with microprocessor circuitry of the instrument compensate for these variations. The paddy sample of the entire lot thoroughly mixed before testing. A measuring cup of C volume was filled with the paddy up to its brim. The measuring cup was properly shaken and leveled to avoid superfluous empty spaces in between the grain. The paddy material was transferred into the test cup. Than the test cup containing the sample in its housing in such a manner that the guide stems of the cup snuggly fits into the hole in the body base. Then selected compression thickness required for paddy (3.25) was selected by rotating the smaller handle in anticlockwise direction. After that the ratchet handle fitted into the open end of bevel pinion and compressed the sample until the reading on the main scale and the circular scale divisions together give the correct thickness reading. Push type switch on the moisture meter was pressed to take the reading after a count down from 10 to 1. The moisture content display had been gave the direct moisture percentage after count down.

Moisture Content Adjustment

The initial moisture content of paddy was determined using the hot air oven (at 130±2˚C until a constant weight was reached) and digital moisture meter. The initial moisture content of paddy was found to be 14.34 % (wb). In order to achieve the desired moisture levels for the study, paddy samples were conditioned by adding calculated quantity of water. The samples were kept in a refrigerator at 4±1°C for a minimum period of 7 days for the moisture to distribute uniformly throughout the paddy. The moisture contents of the samples were equilibrated as per the procedures of [7]. The required amount of sample was withdrawn from the refrigerator and reconditioned at room temperature (30±2°C) before conducting each test [8].

FT-NIR spectroscopy

FT-NIR spectra were recorded on multipurpose analyzer (MPA) (Bruker Optics, Germany) equipped with an integrated Michelson interferometer; highly sensitive PbS 12000-4000 cm^{-1} detector, multiple NIR measurement accessories for different sampling techniques combined with opus 7.2 software. For the current study spectra's were collected in diffuse reflectance mode with sphere macro sample integrating sphere measurement channel. The spectra were acquired in reflectance mode directly on the paddy, over the range 12000–4000 cm^{-1}. For each sampling, 15 g of paddy were analyzed at room temperature and the average spectra were used for further evaluations.

Calibration and Validation Method

The samples were divided into different portions for standard preparations (15 gram each). Moisture content was estimated in 150 samples by using digital moisture meter and air oven method. The standard values were fed into NIR library and 50 samples were validated by using suitable chemometric method.

Data analysis

The OPUS 7.2 software package was used for processing the data and FT-NIR models were developed with the full calibration data set. The spectral data were analyzed using PLS regression with various preprocessing techniques. In this study three spectral preprocessing methods were applied comparatively; it includes vector normalization, first derivative and first derivative plus vector normalization. Vector normalization normalizes a spectrum by first calculating the average intensity value and subsequent subtraction of this value from the spectrum. The sum of the squared intensities is calculated and the spectrum is divided by the square root of this sum. This method is used to account for different samples thickness. The performance of final PLS model was evaluated in terms of root mean square error of cross validation (RMSECV), RPD (residual predictive deviation) and correlation coefficient of determination R^2. Ratio of standard deviation to standard error of prediction gives RPD value (SD/SEP). The accuracy of the calibration models is obtained according to the largest values of R^2 and RPD and smallest values obtained for RMSECV for cross validation.

RESULTS AND DISCUSSION

Spectral information

A calibration models were developed using moisture content standards of varying concentrations in the near-infrared region (4000–12500 cm^{-1}) is shown in Fig. 1. From the figure it is seen that almost spectra of all samples are parallel. Which means the response of the detector for the sample is linear within the range of study and thus may give better results [9]. As the spectra show similar basic FT-NIR spectral patterns, mathematical transformations were required to use the FT-NIR data for quantitative analysis. Despite the lack of distinct peaks, it has been shown the PLS can extract relevant information for quantitative determinations [10].

Fig. 2 shows the FT-NIR spectra of moisture content which has major peaks at absorbance bands (wave numbers) of 3633.42, 3996, 5184, 6834.85 and 8316 cm^{-1}. These true peaks were selected after smoothing the spectrum to avoid interference due to noise. Each chemical bond in a molecule vibrates at a frequency which is characteristic of that bond. A group of atoms in a molecule may have multiple modes of oscillation caused by the stretching and bending motions of the group.

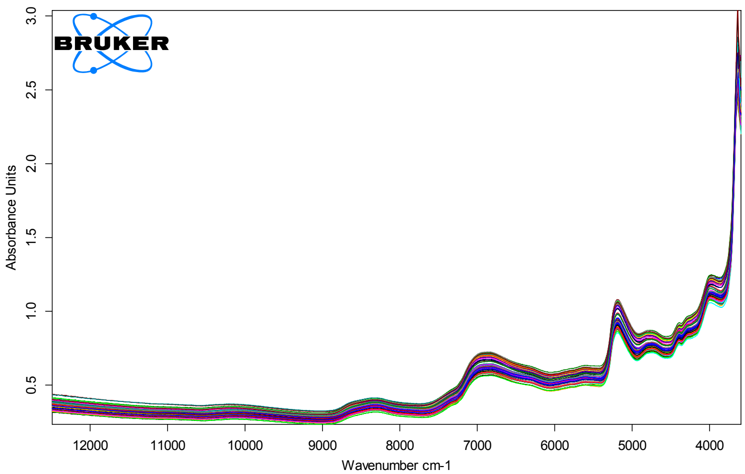


Figure 1. Spectra of paddy samples

The fundamental vibrations in the 4000–3500 cm^{-1} region are generally due to O–H, C–H and N–H stretching. O–H stretching produces a broad band that occurs in the range 3700–3600 cm^{-1}. Hydrogen bonding is very important effect in infrared spectroscopy. This bonding influences the bond stiffness and so alters the frequency of vibration. The presence of hydrogen bonding is of great importance in a range of molecules [11].

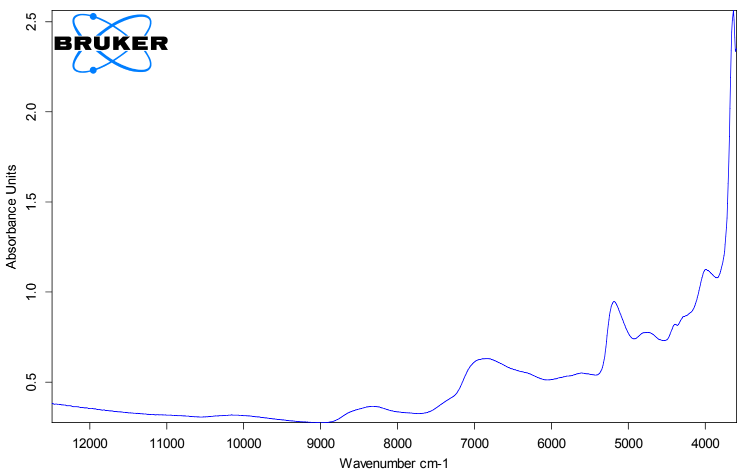


Figure 2. Preprocessed FT- NIR Spectra of paddy sample

Major peaks at absorbance bands or wave numbers of 5184 and 6834.85 cm^{-1} may be due to the OH stretching plus OH bending and first overtone of OH anti-symmetric stretching plus OH symmetric stretching of moisture content respectively. Peaks at 8316 cm^{-1} may be due to second overtone of symmetric stretching (–CH bonds) of methyl (–

CH_3) groups. Stretching a bond requires more energy than to bend it. The energy or frequency that characterizes the stretching vibration of a given bond is proportional to the bond dissociation energy. Water molecule has OH groups on structure; hence, the peak may play an important role in the estimation of moisture. Some minor peaks observed in the paddy spectrum may be due to unknown bond vibrations.

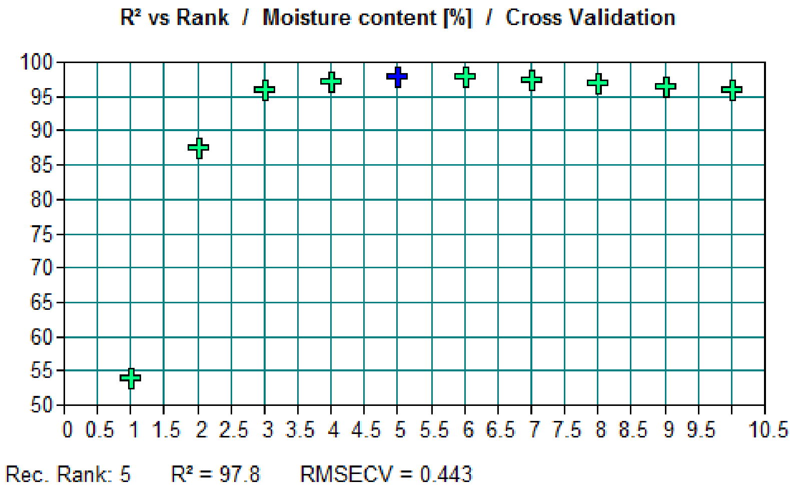


Figure 3. R^2 value as a function of PLS factor

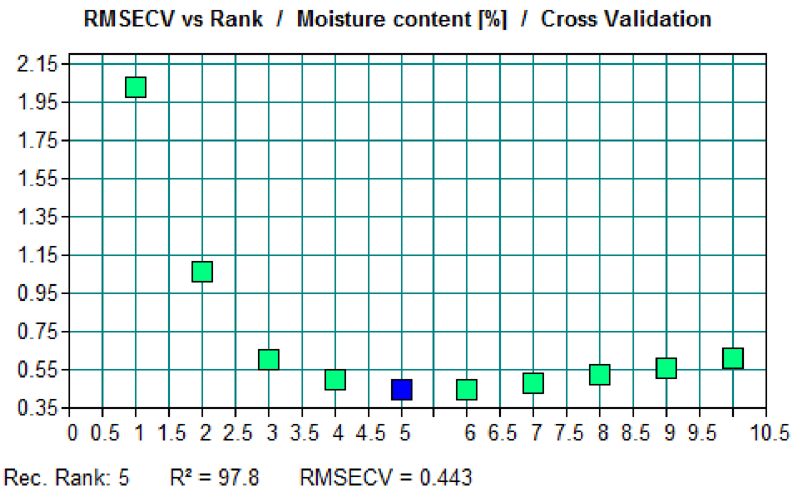


Figure 4. RMSECV as a function of PLS factor

Figures 3, 4 and 5 show the R^2, RMSECV and RMSEE values plotted as a function of PLS factors for determining moisture content with first derivative plus vector normalization method as the pre-processing technique. First derivative method emphasizes steep edges of a peak. It is used to emphasize pronounced, but small features over a broad background. Seen from figure, R^2 value increased up to certain limit and reached a maximum value after that it slightly decrease. RMSECV value decreases sharply up to the recording rank of 5 with initial factors and maintain the constant value as PLS factor increases from 5 to 6. RMSEE value decreases sharply if PLS factor increase. From the figure, conform that initial PLS factor had high impact on R^2, RMSECV and RMSEE values. If PLS factor increases it increase the R^2 value and decrease the RMSECV and RMSEE value.

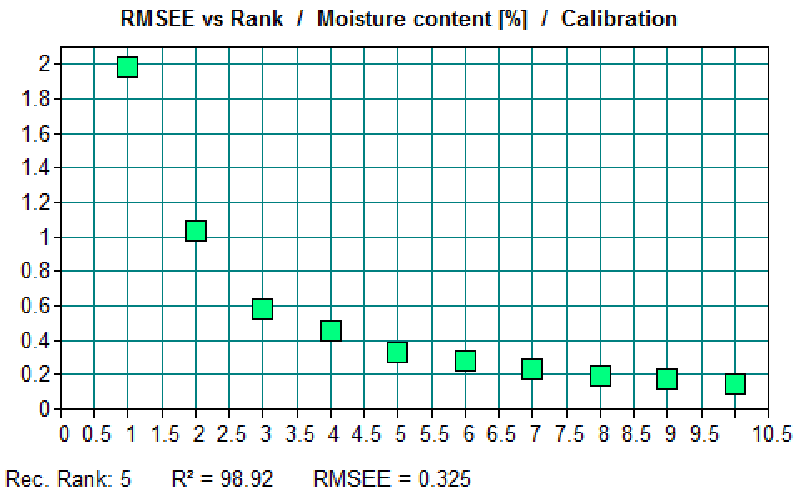


Figure 5. RMSEE as a function of PLS factor

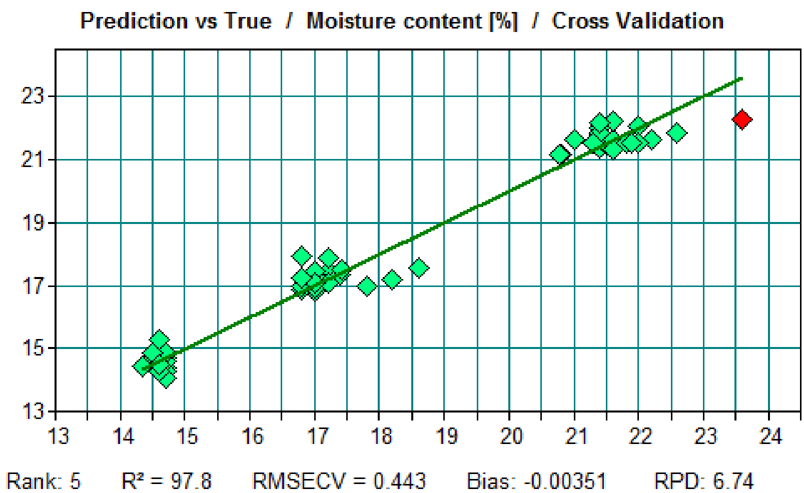


Figure 6. Cross validation of paddy samples for moisture content

Cross validation was also done to check the calibrated values are shown in Fig. 6. The optimum number of factors is determined by the lowest RMSECV and highest value for R^2 and RPD. PLS regression method gave R^2 values of 97.8 and RMSECV value of 0.443 respectively. RPD value was more than 6. If RPD value lower than 1.5 is considered insufficient for most applications while NIR cross validation models with values greater than two is considered excellent [12]. The results of this study clearly indicate the efficiency of FT-NIR for this application.

Comparison analysis of paddy samples with conventional methods

Paddy samples prepared were analyzed by FT-NIR spectroscopy and developed chemometric method was applied to quantify the moisture content in paddy samples. Results obtained from FT-NIR spectroscopy were compared with that of the laboratory methods are shown in Table 1. Results obtained from FT-NIR method were found to be approximately equal to air oven and digital moisture meter method.

Table 1. Comparison of results obtained by air oven, indirect and FT-NIR methods for moisture content determination

	Moisture content by hot air oven method (%, w.b.)	*Moisture content by digital moisture meter (%, w.b.)*	*Moisture content by FT-NIR method (%, w.b.)*
Min	*14.34*	*14.52*	*14.07*
Max	*23.6*	*22.47*	*22.28*
Mean	*17.83*	*17.94*	*17.84*
*SD**	*3.008*	*3.11*	*2.98*

**Standard deviation*

CONCLUSIONS

Results of this study show that NIR spectroscopy could support the conventional techniques in studying the moisture content of paddy. The main advantage of using the NIR spectroscopic techniques is to rapidly draw a profile of the paddy related to its quality. Lower values of RMSECV and RMSEE and relatively higher values of R^2 showed that NIR spectroscopy has potential to predict the moisture content of paddy nondestructively with almost same accuracy as that of laboratory method. The developed models ware applied to forecast moisture content in paddy samples within 15 seconds. This study is useful for CWC (central warehousing corporation) at the time of procurement of paddy from farmers and various paddy research institutions for analyzing the quality of paddy.

BIBLIOGRAPHY

[1] Vitazek, I., Stranak, T. 2013. Application of cooling in post harvest handling of grain. *Scientific journal Agricultural Engineering, Vol. 2013/*4, pp.55-64.

[2] Uddin, M., Okazaki, E., Fukushima, H., Turza, S., Yuniko, Y., Fukuda, Y. 2006. Nondestructive Determination of Water and Protein in Surimi by Near-Infrared Spectroscopy, *Food Chem*., 96, pp. 491-497.

[3] Egidio, V.D., Sinelli, N., Limbo, S., Torri, L., Franzetti, L., Casiraghi, E. 2009. Evaluation of shelf-life of fresh-cut pineapple using FT-NIR and FT-IR spectroscopy. *Post harvest Biology and Technology*, 54, pp.87–92.

[4] Murray, I., Cowe, I. 2004. *Sample preparation*. In: Roberts, C.A., Workman, J., Reeves, J.B. (eds.), *Near Infrared Spectroscopy in Agriculture.* American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. Madison, Wisconsin, USA, pp. 75–115.

[5] Tripathi, S., Mishra, H. 2009. A rapid FT-NIR method for estimation of aflatoxin B_1 in red chili powder. *Food Control*, 20(9), pp.840-846.

[6] Saeed, M., Ali Reza, A.., Hamid., F., Marya, S., Nuria, P. 2012. Determination of Protein and Moisture in Fishmeal by Near-Infrared Reflectance Spectroscopy and Multivariate Regression Based on Partial Least Squares. *Iran. J. Chem. Chem. Eng.,* 31(3), pp.*51-60.*

[7] AOAC. 1995. Official methods of analysis. Washington DC. *Association of Official Analytical Chemists.*

[8] Pandiselvam, R., Kailappan, R., Pragalyaashree, M.M., Daniel Smith. 2013. Frictional, Mechanical and Aerodynamic Properties of Onion Seeds. *International Journal of Engineering Research & Technology,* 2 (10), pp.2647-2657.

[9] Pettersson, H., Aberg, L. 2003. Near infrared spectroscopy for determination of mycotoxins in cereals. *Food Control*, 14(4), pp.229-232.

[10] McShane, M. J., Cote, G. L. 1998. Near-infrared spectroscopy for determination of glucose lactate, and ammonia in cell culture media. *Applied Spectroscopy*, 52, pp.1073–1078.

[11] Stuart, B. 2004. Infrared Spectroscopy: Fundamentals and Applications. John Wiley & Sons, Ltd. Pp. 14-16.

[12] Chang, C.W., Laird, D.A., Mausbach, M.J., Hurburgh, C.R. 2001. Near infrared reflectance spectroscopy-principal component analysis of soil properties. *Soil Sci. Soc. Am.,* 65, pp.480–490.

FURIJEOVA TRANSFORMACIJA SPEKTROSKOPIJE U BLISKOJ INFRACRVENOJ OBLASTI ZA NEDESTRUKTIVNO I BRZO MERENJE SADRŽAJA VLAGE U ZRNU PIRINČA

Pandiselvam Ravi[1], Thirupathi Venkatachalam[1], Vennila Palanisamy[2]

[1]*Tamil Nadu Poljoprivredni univerzitet, Institut za inženjering hrane i poljoprivrednih procesa, Coimbatore. India*
[2]*Centar za post žetvenu tehnologiju, Coimbatore, India*

Sažetak: Tačno merenje sadržaja vlage u celom zrnu pirinča je osnova efikasne kontrole njegovog kvaliteta. Primenjivost merenja vlage u celom zrnu pirinča bilo je ispitivano Furijeovom transformacijom sprektroskopske tehnike u bliskoj infracrvenoj oblasti (FT-NIR). Kalibracioni model je razvijen upotrebom standarda variranja sadržaja vlage za pirinač u bliskoj IC oblasti (4000–12000 cm^{-1}). Razvijeni model je ocenjen. FT-NIR spektroskopija sa hemometrijom, upotrebom PLS–prvih derivata plus metod normalizacije vektora može da predvidi sadržaj vlage u uzorcima pirinča sa tačnošću do koeficijenta korelacije (R^2) većeg od 0.97, RPD (rezidualna devijacija predviđanja) veća od 6 i greška korena srednjeg kvadrata unakrsne validacije (RMSECV) manja od 0.5 sa 5 faktora u prediktivnom modelu. Razvijeni model bio je primenjen da predvidi sadržaj vlage u uzorcima pirinča za 10-12 sekundi. Razvijeni postupak dalje je ocenjivana povratnim studijama poređenjem sa metodom rerne i indirektnim metodom (digitalni merač vlage) za određivanje vlažnosti.

Ključne reči: *NIR spektroskopija, hemometrija, pirinač, sadržaj vlage, kalibracija, validacija, PLS faktor*

Prijavljen:
Submitted: 25.04.2014.

Ispravljen:
Revised:

Prihvaćen:
Accepted: 25.08.2014.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 41 – 51

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 41 – 51

UDK: 631.354

Originalni naučni rad
Original scientific paper

ENERGY SCENARIO IN WHEAT PRODUCTION AND POSSIBLE WAY TO CURTAIL ENERGY FOR TARAI CONDITION OF UTTARAKHAND, INDIA

Raghuraj Singh[1*], Om Prakash Gupta[2]

[1]*Directorate of Medicinal and Aromatic Plants Research, Boriavi (Anand), Gujarat, India*
[2] *G.B. Pant University of Agriculture and Technology, College of Technology, Department of farm Machinery and Power Engineering, Pantnagar(Uttarakhand), India*

Abstract: The production and productivity are directly related with use in unit operation of agricultural production. The variation in yield of crop occurs in India due to wide variation in energy inputs, agro-climatic conditions and resources used. Keeping this in view, a study has been carried out to find the energy scenario of wheat crop and to optimize energy inputs for wheat production in Tarai region of Uttarakhand, India. The scenario shows, energy consumption was highest in tractor farm followed by mixed farm in wheat crop for Tarai region of Uttarakhand. In general, it was observed that fertilizer was the highest energy consuming source for wheat production. Threshing was highest energy consuming operation, which generally ranged from 31 to 36 per cent of total operational energy. The consumption of total energy ranged from 16308 to 20157 $MJ\cdot ha^{-1}$ for wheat crop in Tarai region. The yield and energy productivity of wheat crop can be improved by using optimum energy resource allocations obtained through optimization by 4150 to 6000 $kg\cdot ha^{-1}$ and 0.254 to 0.418 $MJ\cdot kg^{-1}$ respectively. Through use of optimization technique and recommended package of energy inputs the easily achievable yield in case of wheat is 6000 $kg\cdot ha^{-1}$ in Tarai region of Uttarakhand.

Key words: *energy scenario, energy inputs, optimization, energy productivity*

[*] Corresponding author. E-mail: raghuraj9271@gmail.com

Based on part of the thesis submitted to GBPUAT, Pantnagar

INTRODUCTION

Advance technology has created an energy intensive life style. Modern agriculture is no exception to it. India has become self sufficient in food production by adopting improved technologies in agriculture. The present level of production is an outcome of use of high yielding varieties of seeds, chemicals, fertilizers, pesticides, improved irrigation facilities, more area under irrigation, more area under crop, higher level of mechanization, better marketing facilities, well defined credit policies and support price of food grains. In our country (India) wheat production was 68.76 million tons in 2000-01. It has reached 94.88 million tons in 2011-12. The production and productivity is directly related with energy availability. This availability of power in Punjab is 3.5 $kW·ha^{-1}$, which is highest in the country while average power availability in agriculture for whole country is 1.5 $kW·ha^{-1}$. To obtain still more production and productivity, higher energy inputs and better management of food production is required. Energy is an essential input for economic development and improving the quality of life.

The development of conventional as well as non-conventional forms of energy is necessary for meeting the growing demand of energy needs of society. The power generation in India has increased from 1400 MW in 1947 to 2.00 Lakhs MW at the end of 2010-11, which is comprised of power from hydroelectric, thermal, wind and nuclear power stations. The power availability for production agriculture in India is 1.5 $kW·ha^{-1}$ and lies higher its requirement in Punjab which is about 3.5 $kW·ha^{-1}$. In comparison of above Japan is the highest energy consuming country, where the energy input to agriculture production is 14.0 $kW·ha^{-1}$. The optimization of energy inputs in agricultural production by some researchers have shown that all kind of energies are interrelated to each other in crop production.

Ozkan and Firsby (1981) [4] used linear programming technique for optimizing power level and matching implements on multi cropped farm growing corn, soybean, wheat and alfalfa. The authors found that the initial conditions of the farm could be revised to increase net energy return by 30 per cent. Mishra *et al.* (1989) [2] studied the energy requirements for growing wheat after harvesting of paddy with different machinery management systems being used in Nainital district. Energy inflow ranged 15.3 to 17.4 $GJ·ha^{-1}$ and outflow of 77.0 to 106.5 $GJ·ha^{-1}$. Gupta *et al.* (1992) [1] conducted the experiments at Pantnagar to find out energy use in maize-wheat rotation using different tillage treatments. Maximum yield of 4683 $kg·ha^{-1}$ (output energy 70531 $MJ·ha^{-1}$) of wheat was found with tillage treatment of one pass of harrow plough + two pass of harrow and two pass of wooden leveler. The output-input energy ratio for grain was 3.6 and by-product 8.2.

Singh and Singh (1996) [3] conducted survey in Meerut district of Northern India on energy requirement in production of wheat and maize crop. Fertilizer energy input was found to affect wheat and maize yield more than irrigation energy while irrigation energy input was most influencing on sugarcane. In general crops yield did not show any direct relation with tillage energy. The study on energy optimization in crop production is highly scanty using linear programming especially in Uttarakhand. Management for energy use in crop production is highly essential to prevent leakage.

MATERIAL AND METHODS

Study has been carried out to find the energy scenario of wheat crop and to optimize the energy inputs for wheat in Tarai region of Uttarakhand. The data were collected on prescribed proforma using multistage sampling technique by individual interviewing method including all categories of farmers. The selected villages were Phoolsungi and Khamariya in Tarai region of Uttarakhand. Under All India Coordinated Research Project "Energy Requirement in Agricultural Sector" energy data were collected from the selected villages of Tarai region of Uttarankhand in the years 1986-87, 1995-96, 1996-97 and 2000-2001. These survey years were termed as first, second, third and fourth round of survey respectively for wheat crop in Tarai region. The informations collected from the farmers were transformed into computer data sheet as per requirement of energy calculation, and results were obtained from energy FORTRAN-77 computer programmes. The analysis carried out in MS Excel and energy scenario was prepared for wheat crop. The statistical analysis was performed with SPSS 7.5 computer software programme using linear regression model. The outlier points were removed. After removal of outlier points the optimization of energy inputs was done using linear programming technique of What's Best 4.0 package with the simulated energy inputs data sets.

Table 1. Energy calculation

Yield =	$\sum_{i=1}^{n} Y_i X_i^*$	*Human energy =*	$\sum_{i=1}^{n} h_i X_i^*$
Animal energy =	$\sum_{i=1}^{n} an_i X_i^*$	*Diesel energy =*	$\sum_{i=1}^{n} d_i X_i^*$
Electrical energy =	$\sum_{i=1}^{n} e_i X_i^*$	*Seed energy =*	$\sum_{i=1}^{n} s_i X_i^*$
Fertilizer energy =	$\sum_{i=1}^{n} f_i X_i^*$	*Machine energy =*	$\sum_{i=1}^{n} m_i X_i^*$
Chemical energy =	$\sum_{i=1}^{n} c_i X_i^*$	*Total energy =*	$\sum_{i=1}^{n} t_i X_i^*$

where $t_i = h_i + an_i + d_i + e_i + f_i + s_i + m_i + c_i$

Total energy is the sum of the energy usage from different sources.

To maximizing the yield, data were analyzed with the help of linear programming (L.P).

$$\text{Maximize yield} = \sum_{i=1}^{n} Y_i X_i \tag{1}$$

Where:

Y_i [kg·ha^{-1}] - yield level per activity,

X_i [ha^{-1}] - farm area per activity.

Subject to constraints the upper limit of energy sources used by the farmers. When no explicit lower bounds are specified, LP assumes lower bounds are zero.

RESULTS AND DISCUSSION

Changing scenario of energy use pattern in wheat cultivation

The data collected from selected villages of Tarai region for four rounds of survey were analyzed and compared for wheat crop with the first round of survey. Source wise, operation wise, use of different implements/equipments and significance of different sources on wheat production is discussed for mixed and tractor farms and animal farms is not discussed as these were not available.

Source wise energy use pattern in wheat cultivation for tractor farms with four rounds of survey results is presented in Tab 2. It is evident from this table that tractor farms were present in each round of survey in the study area. The tractor farms decreased from 83 to 78 in numbers within time span of 1986 to 2000 year because of combining of the some tractor farms. Whereas mixed farms decreased from 4 in first round to 2 in fourth round in the same period. These farms have been changed to tractor farms with pace of time. Table 1 show that the total energy use in tractor farms for wheat production has decreased by 2.26%, 0.10% and 19.09% in second, third and fourth round with respect to first round of survey, respectively. The overall use of human energy has decreased by 34.73% in fourth round with respect to first round of survey whereas it has decreased by 35.74% and 3% in second and third round of survey with respect to first round. It is due to increased use of matching implements with power source. The use of diesel energy has decreased by 9.43%, 8.97% and 31.73% in second, third and fourth round of survey respectively due to above cited reason. The use of electric energy has increased by 13.56%, 23.23% and decreased by 38.41% in second, third and fourth round of survey with respect to first round of survey respectively due to availability of electric supply in the area. Use of seed energy has decreased by 5.79%, 5.21% and 12.38% in second, third and fourth round with respect to first round of survey respectively due to use of efficient and certified seeds. Fertilizer energy use has increased by 3.65% and 10.72% in second and third round with respect to first round of survey to increase the yield of wheat crop whereas it was more or less constant in third round. The chemical energy has decreased by 79.85%, 79.04% and 82.35% in second, third and fourth round with respect to first round of survey respectively due to use of disease resistant high yielding varieties. Use of machinery energy has increased by 19.96% in second round with respect to first round of survey whereas it has decreased by 1.85% and 11.61% in third and fourth round of survey due to use of improved implements. The use of canal energy has increased by 40.05%, 18.86% and decreased by 11.50% in second, third and fourth round respectively with respect to first round of survey depending upon the availability of water in canal and requirement. Canal is the cheapest source of water for irrigation purpose. The use of direct energy has decreased by 5.64%, 1.24% and 33.54% in second, third and fourth round of survey with respect to first round respectively. Indirect energy has decreased by 11.32% in fourth round of survey with respect to first round. The energy productivity has increased by 15.86%, 17.60% and 64.68 in second, third and fourth round with respect to first round of survey due to increase use of fertilizer and better quality seeds in wheat cultivation

Table 2. Source wise energy use pattern in wheat cultivation on irrigated tractor farm in Tarai region of Uttarakhand (MJ·ha^{-1})

Source	I Round	II Round	III Round	IV Round	%Change in II round w.r.t. 1st round	%Change in III round w.r.t. 1st round	%Change in IV round w.r.t. 1st round
Human	399	257	387	253	-35.74	-3.00	-36.69
Diesel	5029	4555	4578	3434	-9.43	-8.97	-31.73
Electric	1619	1839	1995	997	13.56	23.23	-38.41
Seeds	1746	1645	1655	1530	-5.79	-5.21	-12.38
Fertilizer	7963	8254	8817	7975	3.65	10.72	0.15
Chemical	1255	253	263	221	-79.85	-79.04	-82.35
Machinery	522	626	512	461	19.96	-1.85	-11.61
Canal	1624	2274	1930	1437	40.05	18.86	-11.50
Total(MJ·ha^{-1})	20157	19702	20138	16308	-2.26	-0.10	-19.09
Direct	7048	6650	6961	4684	-5.64	-1.24	-33.54
Indirect	13110	13052	13177	11625	-0.44	0.52	-11.32
Renewable	2146	1902	2043	1783	-11.36	-4.80	-16.91
Nonrenewable	18012	17801	18096	14526	1.17	0.46	-19.35
Commercial	19758	19446	19751	16056	-1.58	-0.04	-18.74
Noncommercial	399	257	387	253	-35.74	-3.00	-36.69
Energy productivity	0.155	0.179	0.182	0.254	15.86	17.60	64.68
Yield (kg·ha^{-1})	3115	3527	3660	4150	13.25	17.49	33.23

The operation wise energy use in wheat cultivation for tractor farms with four rounds of survey results is presented in Tab. 3. It is evident from this table that the total energy used in different operations has increased by 13.18% and 5.32% in second and third round whereas it has decreased by 9.73% in fourth round with respect to first round of survey as presented in Tab. 3. The use of tillage energy has decreased by 9.68%, 13.55% and 43.90% in second, third and fourth round of survey with respect to first round due to increase in use of matching implements with power source. Sowing energy was more or less constant in second and third round whereas it has decreased by 16.76% in fourth round survey with respect to first round. The use of irrigation energy has increased by 10.98%, 8.81% and decreased by 25.86% in second, third and fourth round with respect to first round of survey due to demand of water by high yielding varieties of wheat and efficient use of water. Spraying energy has increased by 5.04%, 254.24% and 147.49% in second, third and fourth round with respect to first round of survey due to increase use of herbicide. Weeding energy was more or less constant in last three rounds of survey. The use of harvesting energy has increased by 128.36%, 34.02% and 67.42% in second, third and fourth round with respect to first round of survey whereas threshing energy has also increased by 18.62%, 7.51% and 32.0% in the same period with respect to first round of survey due to increase in production of wheat crop. Transportation energy has increased by 152.95%, 34.62% and 172.24% in second, third and fourth round of survey with respect to first round of survey which is obvious due to increase in transportation of main product and by product.

Table 3. Operation wise energy use pattern in wheat cultivation on irrigated tractor farm in Tarai region of Uttarakhand (MJ.ha^{-1})

Operations	I Round	II Round	III Round	IV Round	%Change in II round w.r.t. Ist round	%Change in III round w.r.t. Ist round	%Change in IV round w.r.t. Ist round
Tillage	2944	2659	2545	1651	-9.68	-13.55	-43.90
Sowing	393	396	396	327	0.74	0.69	-16.76
B.M	0	0	117	24	0.00	0.00	0.00
Irrigation	2007	2228	2184	1488	10.98	8.81	-25.86
Weeding	0	114	193	111	0.00	0.00	0.00
F.A.	16	13	21	10	-19.44	38.32	-34.59
Spray	5	6	19	13	5.04	254.24	147.49
Harvesting	384	876	514	642	128.36	34.02	67.42
Threshing	1849	2194	1988	2441	18.62	7.51	32.00
Transportation	82	208	111	224	152.95	34.62	172.24
Total (MJ·ha^{-1})	7680	8692	8088	6932	13.18	5.32	-9.73

The regression coefficients for different sources of energy impacts were determined The seed energy has been found significant at 1% level of significant (*LOS*) and machinery energy at 5% *LOS* in first round of survey. The canal, chemical, diesel, fertilizer, human and machinery energy have been found significant at 1% *LOS* in second round of survey. The diesel, electrical and fertilizer energy have been found significant at 1% *LOS* in third round of survey whereas human energy is significant at 5% *LOS* in third round of survey. The chemical and seed energies have been found significant at 5% *LOS* in fourth round of survey whereas fertilizer energy and human energy is significant at 1% and 10% *LOS* in fourth round of survey respectively.

Energy use pattern for mixed and tractor farms in Tarai region of Uttarakhand for wheat cultivation at last round of survey

A comparison has been made to represent the overall energy use pattern in mixed and tractor farms for fourth round of survey in Tarai region of Uttarakhand. Animal farms are not included because no farm in this category was available. It is clear that out of total energy consumption in wheat cultivation the most energy consuming source was fertilizer (48.89 to 58.11%), followed by diesel (9.03% to 21.06%), seed (9.38% to 10.40%), canal (8.81% to 8.91%), animal (0% to 6.30%), electric (0% to 6.11%), human (1.55% to 3.95%), machinery (1.89% to 12.83%) and chemical energy (1.36% to 1.42%). The yield of wheat was higher in tractor farms (4182 kg·ha^{-1}) followed by mixed farms (3872 kg·ha^{-1}).

Comparison of operation wise energy use in mixed and tractor farms for wheat cultivation in fourth round of survey for Tarai region shows that threshing energy has consumed the highest share (31.97% to 35.22%) out of total operational energy followed by tillage energy (23.82% to 25.1%), irrigation energy (21.47% to 26.57%), harvesting energy (8.59% to 9.26%), sowing energy (4.42% to 4.72%), transportation energy (2.57% to 3.23%), weeding energy (0 to 1.6%), bund making energy (0.35% to 0.41%), spraying energy (0.19 to 0.21%) and fertilizer application energy (0.14% to 0.16%) respectively.

Optimization of energy inputs in production of wheat crop

In the prevalent crop production system there exists a scope of improvement in terms of net energy return and energy efficiency. There is a possibility that an increase up to a certain limit in crop production inputs would cause an increase in crop output also. The farmers may not always be able to use more inputs because of their high prices. To bring forth better results from the existing energy use patterns, it is thus suggested that optimization of existing energy inputs be done with the simulated data sets. In view of this energy data sets have been optimized using linear programming technique by maximization of objective function i.e. yield of wheat crop under the given set of energy input (s) constraints. The optimization has been done for wheat crop in Tarai region of Uttarakhand. The models are formulated assuming linear crop production function and constraints so that liner programming could be used to obtain the optimal solution. The optimal allocation would, thus indicate the utilization of energy input resources on the farm for a particular crop with saving of energy resources wherever possible. The optimization has been done only for present actual farm practice with simulated energy input data. The average energy use in tractor farms for wheat cultivation in Tarai region of study area is presented in Tab. 4. The average yield of wheat crop has been found 4150 kg.ha-1 in study area under actual farm cultivation. The sources used in wheat cultivation are human, diesel, electric, seeds, fertilizer, chemical, machinery and canal. The fertilizer energy and diesel energy are main energy consuming sources in wheat cultivation. The share of human, diesel, electric, seeds, fertilizer, chemical, machinery and canal energy input is 1.55%, 21.06, 6.11, 9.38, 48.90, 1.36, 2.82 and 8.81 percent respectively. The average energy productivity has been found 0.254 $kg{\cdot}MJ^{-1}$. Use of electricity is only in irrigation and threshing of wheat crop.

Table 4. Source wise average energy use pattern ($MJ{\cdot}ha^{-1}$) in wheat cultivation under actual farm practices for irrigated tractor farm in Tarai region of Uttarakhand

Yield ($kg{\cdot}ha^{-1}$)	*HUM*	*ANI*	*DSL*	*ELE*	*SEEDS*	*FYM*	*FER*	*CHE*	*MACH*	*CAN*	*TE*	*E.PROD*
4150	*253*	*0*	*3434*	*997*	*1530*	*0*	*7975*	*221*	*461*	*1437*	*16308*	*0.254*

The Tab. 5 represents optimum energy resource allocation with maximum yield under actual farm practice i.e. existing farm practice. The yield of wheat has increased by 30.98% from 4150 to 5436 $kg{\cdot}ha^{-1}$ due to use of optimum energy resource allocation in actual farm practice. The consumption of energy inputs would save 44.27% human, 22.95% diesel, 29.39% seeds, 33.03% chemical and 1.30 % machinery energy as compared to existing farm practice used in wheat cultivation whereas the energy input consumption of seed and fertilizer energy input has exceeded by 6.86% and 2.01% respectively. The more seed energy is required to increase the population of plants in the field while fertilizer energy use is more for increasing the yield of wheat. Thus the total energy used in optimized wheat cultivation has decreased by 14.99% from 16308 to 13864 MJ·ha^{-1}. The energy productivity has increased by 54.33% from 0.254 to 0.392 kg·MJ^{-1} on using optimized energy resource allocation. Thus the energy efficiency can be improved by using quality seeds, better fertilizer combinations, better seed bed preparation, tool combination and use of matching implements with the tractor.

Table 5. Maximum yield and optimum energy resource consumption (MJ.ha^{-1}) under existing farm practices for irrigated tractor farm in Tarai region of Uttarakhand

Yield (kg·ha^{-1})	HUM	ANI	DSL	ELE	SEEDS	FYM	FER	CHE	MACH	CAN	TE	E.PROD
5436	141	0	2646	704	1635	0	8135	148	455	0	13864	0.392

The Tab. 6 shows optimum energy resource allocation with maximum potential yield in wheat cultivation. This set of energy input has been obtained by optimizing the energy inputs with simulated data sets. The yield of wheat crop has increased by 44.58% from 4150 to 6000 kg·ha-1 as compared to actual farm practice average yield. For achieving the potential yield in tractor farms, farm operations would require 24.51% more human energy, 18.14 less diesel energy, 11.74% less electric energy, 9.22% more seed energy, 0.82% more fertilizer energy, 34.39% more chemical energy and 23.43% less machinery energy. The use of canal energy is nil because it does not supply water throughout the year timely. The optimized resource allocation with the simulated data sets can improve the energy productivity by 64.57% from 0.254 to 0.418 kg·MJ^{-1} in tractor farm.

Table 6. Maximum potential yield and optimum energy resource allocation (MJ·ha^{-1}) for irrigated tractor farm in Tarai region of Uttarakhand

Yield (kg·ha^{-1})	HUM	ANI	DSL	ELE	SEEDS	FYM	FER	CHE	MACH	CAN	TE	E.PROD
6000	315	0	2811	880	1671	0	8041	297	353	0	14368	0.418

Table 7. Source wise/operation wise energy use pattern for different levels of productivity with improved cultivation practices in wheat crop cultivation for tractor farm in Tarai region of Uttarakhand

Yield (kg·ha^{-1})	E.PROD (kg·MJ^{-1})	Source wise direct energy consumption (MJ·ha^{-1})				Operation wise energy consumption (MJ·ha^{-1})					
		HUM	ANI	DSL	ELE	TIL	SOW	IRR	HAR	THR	TRP
6000	0.418	315	0	2811	880	0	686	2884	611	0	125
5500	0.414	189	0	2700	663	645	439	1935	713	0	169
5000	0.406	120	0	2357	743	1081	286	1282	756	0	196
4500	0.383	130	0	1977	833	1182	286	1159	740	0	208
4000	0.347	115	0	2138	171	1296	286	1103	788	0	240
3500	0.299	139	0	2556	1294	1630	390	1483	847	0	186
3169	0.213	315	0	3356	1073	1485	415	1279	499	1193	225

The different yield levels achievable with their energy productivity are presented in Tab. 7. The source wise direct energy consumption and main operation wise energy consumption for wheat cultivation are given as obtained by optimizing the energy inputs. It shows a trend that the energy productivity decreases (from 0.418 to 0.213 kg·MJ^{-1}) with decrease in yield levels (from 6000 to 3169 kg·ha^{-1}). It is due to need of more energy inputs with lower yield levels.

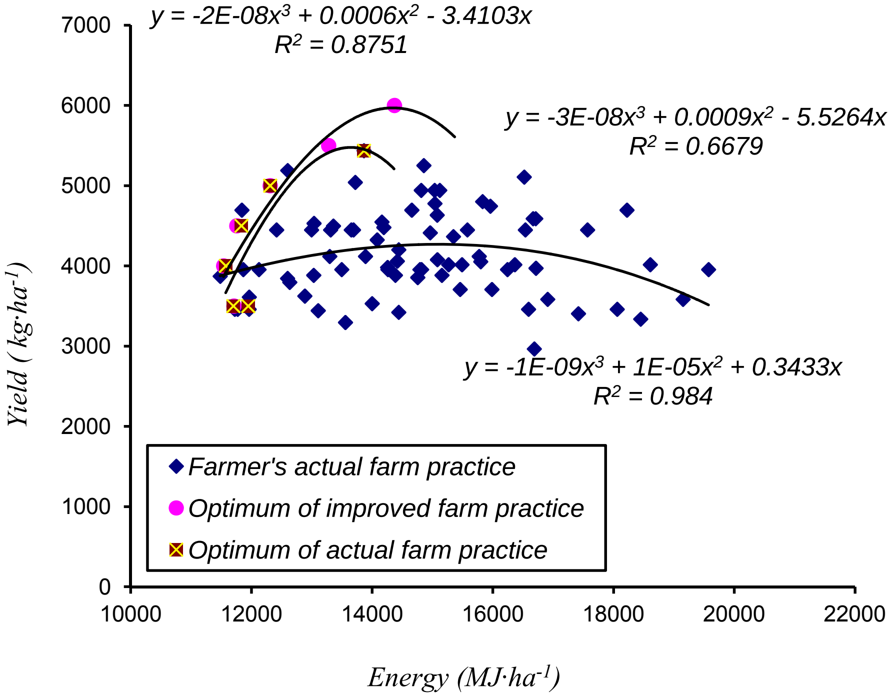


Figure 1. Optimum energy use patterns for different levels of wheat productivity for irrigated tractor farm in Tarai region of Uttarakhand

Fig. 1 represents the total energy use models for farmer's actual farm practice, optimum of actual farm practice and optimum of improved farm practice. It is clear from the trend lines that the optimum of actual farm practice can save the energy in wheat cultivation with increase in yield of wheat crop. The trend line of optimum of improved farm practice further shows that energy used in wheat cultivation can save energy over the optimum actual farm practice with the increase in yield of wheat.

CONCLUSIONS

Thus keeping in view above study, the following conclusions may be drawn:

1. The seed energy and human energies are more or less constant in mixed farms and tractor farms but human energy in mixed farms ranged 430 to 990 MJ·ha^{-1}.

2. The use of total energy use in wheat cultivation has ranged from 16308 to 20157 $MJ \cdot ha^{-1}$ while diesel, electric and fertilizer energy consumption has ranged from 3434-5029, 997-1995 and 7963-8817 $MJ \cdot ha^{-1}$ respectively.
3. The total operational energy use in wheat cultivation has ranged from 6932 to 8692 $MJ \cdot ha^{-1}$ while tillage, irrigation and threshing energies have ranged from 1651-2944, 1488-2228 and 1849-2441 $MJ \cdot ha^{-1}$ respectively.
4. The yield of wheat crop can be increased by 44.58% from 4150 to 6000 $kg \cdot ha^{-1}$ with 11.89% less total energy input (from 16308 to 14368 $MJ \cdot ha^{-1}$) of optimum energy resource allocation with optimum of improved farm practice over actual farm practice in wheat cultivation of tractor farm.
5. The energy productivity of wheat crop can be improved by 64.57% from 0.254 to 0.418 $kg \cdot MJ^{-1}$ with the optimum of improved farm practice over actual farm practice in tractor farm.

BIBLIOGRAPHY

[1] Gupta, O.P., Chhabra, S.D., Mittal, J.P. 1992. Energy and labour inputs under different tillage and weed control combinations for maize and wheat production in India. *Journal of Rural Energy*. 1(1): 11-25.

[2] Mishra, T.N., Singh, B., Singh, K.N., Seth, G.S., Ghosh, A. 1989. Effect of machinery management on energy requirements and yield for wheat after paddy harvesting. *Indian Journal of Agricultural Engineering*. 26(1): 24-29

[3] Singh, A., Singh, A.J. 1996. Energy Consumption pattern in Punjab Agriculture: inter-size and regional variations. *Energy Management, July September*. 31-37.

[4] Ozkan, H.E., James, C.F. 1981. Optimizing field machinery system energy consumption. *Transaction of ASAE*. 24(10): 296-300.

[5] Singh, R.R. 2002 *Studies on energy use pattern for major crops in Tarai and Bhabar region of Uttaranchal (Uttarakhand)*. Unpublished M.Tech. thesis GBPUA&T, Pantnagar

[6] Exim-Bank: Research Brief. 2012. *Technological Intervention in Indian Agriculture for Enhancement of Crop Productivity*. www.eximbankindia.in, No. 68. May 2012

ENERGETSKI SCENARIO U PROIZVODNJI PŠENICE I MOGUĆNOST SMANJENJA POTROŠNJE ENERGIJE U USLOVIMA TARAI UTTARAKHANDA, INDIJA

Raghuraj Singh[1], Om Prakash Gupta[2]

[1] *Direktorat za istraživanje lekovitog i aromatičnog bilja, Boriavi, Gujarat, Indija*
[2] *Univerzitet za poljoprivredu i tehnologiju G.B. Pant, Tehnološki fakultet, Institut za poljoprivredne i pogonske mašine, Uttarakhand, India*

Sažetak: Proizvodnja i produktivnost su direktno povezani sa upotrebom u jediničnim operacijama poljoprivredne proizvodnje. Varijacije u prinosima u Indiji se pojavljuju zbog velikih variranja energetskih inputa, agro-klimatskih uslova i iskorišćenih resursa. Imajući ovo u vidu, izvedeno je istraživanje da bi se našao energetski scenario proizvodnje pšenice i optimizovali energetski inputi u proizvodnju pšenice u regionu Tarai u Uttarakhand, Indija. Scenario pokazuje da je potrošnja energije bila najveća na farmama sa traktorima, a zatim na mešovitim farmama u ovom regionu. Generalno, uočeno je da je đubrivo bilo najveći potrošač energije u ovoj proizvodnji. Vršidba je bila operacija sa najvećom potrošnjom energije, koja je generalno iznosila 31 do 36% od ukupne energije u svim operacijama. Ukupna potrošnja energije u ovom region iznosila je od 16308 do 20157 $MJ \cdot ha^{-1}$. Prinos i energetska produktivnost pšenice mogu da se unaprede upotrebom energetskih resursa sa optimalnih lokacija, dobijenih optimizacijom za 4150 do 6000 $kg \cdot ha^{-1}$ i 0.254 do 0.418 $MJ \cdot kg^{-1}$, redom. Upotrebom tehnike optimizacije i preporučenog paketa energetskih inputa lako je postići prinos pšenice od 6000 $kg \cdot ha^{-1}$ u Tarai regionu Uttarakhanda.

Ključne reči: *energetski scenario, energetski inputi, optimizacija, energetska produktivnost*

Prijavljen: *Submitted*:	31.03.2014.
Ispravljen: *Revised*:	26.09.2014.
Prihvaćen: *Accepted*:	29.09.2014.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 53 – 62

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 53 – 62

UDK: 63 (82)

Originalni naučni rad
Original scientific paper

DEVELOPMENT AND PERFORMANCE EVALUATION OF MOBILE IRRIGATOR FOR DRY LAND AGRICULTURE

Ravi Pandiselvam[1*], Nawab Jan Amreena Jan[1] , Gurusamy Parthasarathi[2], Kunjurayan Rajesh[1], Ganapathy Kaveri[1]

[1] Tamil Nadu Agricultural University, Department of Food and Agricultural Process Engineering, Coimbatore, India
[2] Tamil Nadu Agricultural University, Department of Agricultural Economics, Coimbatore, India

Abstract: This research work was conducted at Agricultural Engineering College and Research Institute, Kumulur located in Tamil Nadu, India. The mobile irrigator was developed for effective utilization of the available water in dry land agriculture instead of following the supplementary irrigation. In case of supplementary irrigation the application efficiency and distribution uniformity is less. It reduces both the yield of crop and the water use efficiency. Hence the aim of the present investigation was to develop a mobile irrigator which could be light in weight and can be moved manually while irrigating. Performance evaluation (application efficiency and distribution uniformity) of the irrigator was tested in a dry land field of maize. The results revealed an acceptable value of application efficiency (74%) and distribution co-efficient (75%). The travel speed and operating pressure were optimized about 2.1 $cm \cdot s^{-1}$ and 245 kPa. The crops for which the system can be used for irrigation are maize, groundnut, pulses, etc. For the efficient performance of the irrigator, the height of the crop should be less than or up to 1.5 m.

Key words: *Mobile irrigator, distribution uniformity, application efficiency, dry land agriculture*

[*] Corresponding author. e-mail: anbupandi1989@yahoo.co.in

INTRODUCTION

Water is one of nature's precious gifts to mankind. With out water there is no life on earth. The available water is declining day by day in India, this is due to the fast growth of population. In order to feed the growing population, agriculture should be improved and from the available land and water, more crops should be produced. Effective planning and utilization of available water resources is very important to meet the current growing demand. Therefore water management and increased crop production is very essential and crucial for the welfare of living beings. The productivity of the land need to be increased, so in order to do it, pressurised irrigation should be used. Sprinkler and drip system are the two types of pressurised irrigation system used in India. In the sprinkler irrigation system there are various types but most of the types are either fixed or difficult to move manually. Research studies conducted in India by various institutions have indicated that the water saving in micro irrigation is about 40–80% with a yield increase of 40-60% for various crops grown in different climatic regions.

The hand move portable lateral system is composed of either a portable or buried main line with valve outlets at various spacing for the portable laterals. This system is used to irrigate more area than any other system, and it is used on almost all crops and all types of topography. The disadvantage of the system is its high labour requirement [1]. [2] Conducted a research on the pressure required of a cable tow irrigation system and found that it is a good indicator of the energy needed to efficiently operate such a system. Self-propelled gun type traveller system is usually the most practical system for irrigating irregular shaped fields [3].

Properly designed irrigation systems can minimise the losses of water delivered to the plants. Water scarcity is one of the major problems in many places of Tamil Nadu as far as agriculture is concerned and also the cost of installation of various types of pressurised irrigation viz. sprinkler and drip irrigation system for any agricultural field. In addition to these difficulties, it was not flexible and the maintenance cost was also very high. So in order to overcome some of the above said difficulties of pressurised irrigation system, an effort was taken to design a farmer friendly system which would be of much use to the farmers.

The objective of this study was to investigate the effective utilisation of available water by applying in the form of spray (using raingun), to reduce the cost of installation of pressurised irrigation system and fabrication of portable irrigation system to irrigate the crop during critical conditions.

MATERIAL AND METHODS

The mobile irrigator consisted of a Rectangular frame, Pneumatic wheel, Wheel supporting frame, Riser, Riser supporting structure, Rain gun, Flexible hose and Cable and drum assembly as shown in Fig. 1.

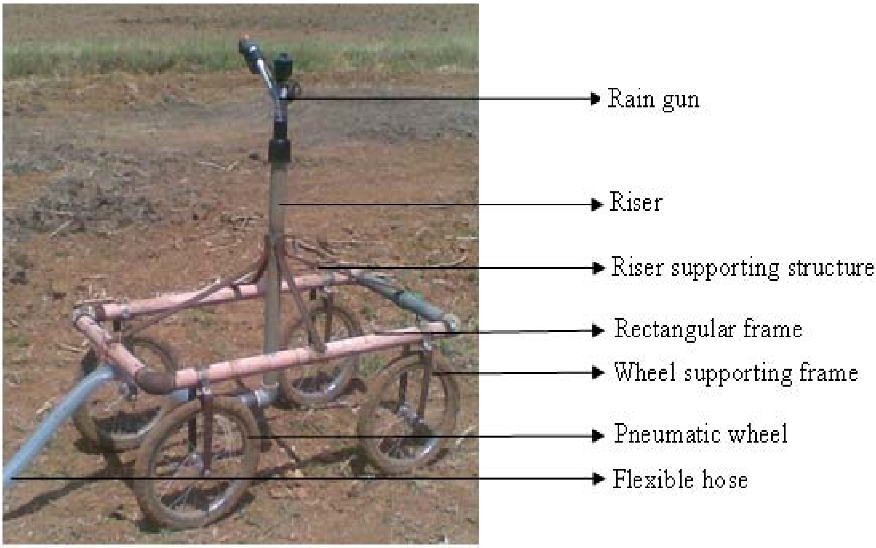


Figure 1. Mobile Irrigator

Rectangular frame

Rectangular frame is made by using galvanized iron hollow pipe material. A rectangular structure frame (100X50 cm) was fabricated. The irrigator moves in the field with the aid of a pneumatic wheel. Four numbers of pneumatic wheels were used. The rim, tier and tube used for this study were 40.64x3.18 cm type. Pneumatic wheel was attached to the main frame of the irrigator by means of an attachment called wheel supporting structure. Riser is the component of the mobile irrigator which was placed vertically at the centre of the rectangular frame. It was made up of galvanized iron pipe and its height was 1 m. It was placed at a height of 20 cm above the ground level. The riser consists of two threaded ends in order to attach rain gun at one end and hose at other end.

Riser supporting structure

The riser cannot be fixed to the frame directly. A supporting structure should be provided in order to attach the frame and also to fix it at a height of 20 cm above the ground level. A mild steel flat rod (1x0.25 cm) was used. The supporting structure was placed at an angle of 50^{o} to the horizontal frame and tag welded. Four pieces of supporting rods were used.

Raingun

A medium sized raingun was used. It nozzle diameter was 6 mm and similar to the two way sprinkler head. The throw length can be adjusted by a screw arrangement provided at the front of the nozzle. It goes a full rotation (360^{o}) when operated.

Flexible hose

The water was supplied from the main water source through the flexible hose to irrigator. The required pressure was created by using different hp motors. The flexible hose of 1.5” (3.75 cm) was used. The hose was connected to the riser through a hose nipple.

Cable and drum arrangement

The irrigator was dragged along the lane in the field manually by means of cable and drum arrangement. One end of the cable was fitted to the rectangular frame and the other end to a rotating drum. When the drum was rotated the cable wounded itself on the drum and by the means of that the irrigator moved in the field. The maximum length of the cable was 70 m. The drum and cable arrangement was mounted on a stand. The drum was rotated by means of handle which was fixed to the drum through the flat rod.

Testing done on Mobile Irrigator

Testing of the mobile irrigator was done at Cotton Research Station located at Veppanthattai in Perambalur district of Tamil Nadu, India. This place is rain fed area. The crop irrigated using the mobile irrigator was at the vegetative phase with two to three leaves per plant and the crop was in critical period under water stress. Soil type at that place was black soil and moisture retaining capacity of the soil was high because of which the crop survived for many days without irrigation. Availability of water is very less so, the water must be effectively utilized. The area under which the crop was raised about one ha. In order to irrigate such large field by any of the surface irrigation method even for a smaller depth the irrigation water requirement would be high and the losses also would be high.

The steps carried out in collecting the data for the calculation of application efficiency and distribution uniformity are as follows:

The mobile irrigator was placed in the field at one end and drum and cable was placed at other end. The flexible hose was fixed at the inlet and to the riser. The length of run was measured and the area to be irrigated was also found. The catch cans were placed at the centre of each run length perpendicular to the lane. The cans were placed at 1 m interval. The system was started and water was collected. The inlet and outlet pressure was measured using a pressure gauge. The time taken to cover the run length was noted. The amount of water collected in the catch can after each run along a single lane was measured and noted. After covering a single lane the irrigator was transferred to the next lane and same procedure was followed. This was done to show the percentage of overlap.

The amount of water collected was measured using a measuring cylinder. The volume was converted into depth of water collected by calculating the can surface area.

$$Depth\ of\ water\ collected\ (cm) = \frac{V}{A} \qquad (1)$$

Where:

V $[cm^3]$ - volume of water collected in catch can,
A $[cm^2]$ - catch can surface area.

Tests were carried out on the mobile irrigator to find out the two main parameters. The parameters calculated were distribution uniformity and application efficiency.

Distribution uniformity

Distribution uniformity is a measure of how uniform the application of water is to the surface of the field. It was tested at different travel speeds (2.1, 3.2 and 5.5 cm per second) and operating pressures (195, 225 and 245 kPa). Mathematically, distribution uniformity can be represented as [5]:

$$DU = (Ave_{LQ} / Ave_T) \times 100 \tag{2}$$

Where:
DU [%] - distribution uniformity,
Ave_{LQ} [mm] - average of the lowest quarter of catch can readings,
Ave_T [mm] - average of all catch can readings.

Application efficiency

Application efficiency is a measure of how efficiently water has been applied to the root zone of the crop. This parameter relates the total volume of water applied by the irrigation system to the volume of water that has been added to the root zone and available for use of the crop. The application efficiency was calculated as [5]:

$$AE = \frac{\frac{Average\ depth\ applied\ (mm)}{100} \times area(ha)}{Water\ delivered\ to\ the\ field\ (ML)} \times 100 \tag{3}$$

Where:
AE [%] application efficiency.

Statistical analysis

Data analyzed using SPSS software. Data of experiment were analyzed by a randomized block design using factorial arrangements of treatments. The analysis of data was performed on each dependent variable using the treatments were compared for significance with ANOVA.

RESULTS AND DISCUSSION

Distribution uniformity

Distribution uniformity was calculated from Tab. 1. It was quite acceptable at 75%, although uniformities in excess of 80% are achievable. Table 2 showed that, F values of distribution uniformity are significant (ρ< 0.01) in travel speed and operating pressure. Travel speed of the irrigator can be adjusted to apply varying amounts of total irrigation. The amount of irrigation applied to an area at one time can be varied by adjusting travel speed. High uniformity distribution achieved at a travel speed of 2.1 cm per second at 245 kPa as compared to 3.2 and 5.5 cm per second. Uniform irrigation is important to ensure maximum production and minimum cost. The value of this parameter decreases as the variation increases. Non uniformity of the applied water can significantly affect irrigation performance [4]. A distribution uniformity of 100% would mean that each and every point with in the irrigated area received the same amount of water.

Table.1. Depth of water applied

Can spacing [m]	*SYSTEM EVALUATION*		*Depth applied [mm] (in ascending order)*
	Depth applied [mm]	*Depth applied [mm]*	
1	18	1.2	1.2
2	26	1.7	1.6
3	32	2.1	1.7
4	40	2.6	1.9
5	46	3.0	2.1
6	46	3.0	2.3
7	46	3.0	2.6
8	46	3.0	2.6
9	48	3.1	2.7
10	42	2.7	2.7
11	40	2.6	2.7
12	44	2.9	2.9
13	46	3.0	2.9
14	48	3.1	2.9
16	44	2.9	2.9
17	46	3.0	3.0
18	50	3.2	3.0
19	56	3.6	3.0
20	50	3.2	3.0
21	50	3.2	3.0
22	56	3.6	3.0
23	48	3.1	3.0
24	48	3.1	3.0
25*	70	4.5	3.1
26*	72	4.7	3.1
27*	68	4.4	3.1
28*	70	4.5	3.1
29*	66	4.3	3.1
30	48	3.1	3.1
31	48	3.1	3.1
32	48	3.1	3.1
33	48	3.1	3.1
34	44	2.9	3.1
35	42	2.7	3.1

36	*44*	*2.9*	*3.1*
37	*48*	*3.1*	*3.1*
38	*50*	*3.2*	*3.1*
40	*48*	*3.1*	*3.2*
41	*46*	*3.0*	*3.2*
42	*48*	*3.1*	*3.2*
43	*48*	*3.1*	*3.2*
44	*50*	*3.2*	*3.2*
45	*50*	*3.2*	*3.2*
46	*52*	*3.4*	*3.4*
47	*48*	*3.1*	*3.6*
48	*48*	*3.1*	*3.6*
49	*46*	*3.0*	*4.3*
50	*42*	*2.7*	*4.4*
51	*36*	*2.3*	*4.5*
52	*30*	*1.9*	*4.5*
53	*24*	*1.6*	*4.7*
54	*24*	*1.6*	*4.7*

** These values indicate the catch cans in which overlap occurred*

Table.2. Variance analysis of distribution uniformity

Distribution Uniformity			
Variables	*df*	*Mean Square*	*F*
Travel Speed (S)	*2*	*311.50*	*97.95***
Operating Pressure (P)	*2*	*203.78*	*48.51***
*S*P*	*4*	*190.64*	*29.26***
Total	*8*	*-*	*-*

***p is significant at 0.01 levels.*

Distribution uniformity is primarily influenced by the system design criteria. Poor uniformity of application is often easily identified by differences in crop response and evidence of surface water logging or dryness. Because of obvious nature of the crop effects associated with poor distribution uniformities, increasing the uniformity is often seen as a strategy to improve crop yield rather than provide water savings. However, poor distribution uniformity does suggest that there is more likelihood of localized over-irrigation and hence, improvements in uniformity are commonly necessary as a precursor to direct water application efficiencies. It should be noted that distribution uniformity is calculated over the actual irrigated area and not the irrigable area. This means that distribution uniformity data must be considered for whole wetted area and not just within the boundaries of the crop being irrigated.

Non-uniformity of irrigation application will result in some sections of the field being over or under watered. While the average depth of water applied to a total given area may be known, one half of the total area will have received less than the average applied while the other half will have received more water than the average. In this case the half receiving more than the average may suffer from inefficiencies due to water logging or run-off, while the half receiving less than average may suffer from water stress. Often, if the non-uniformity is quite significant, this over or under watering is visible in the growth of the crop. Research indicates that distribution uniformity is affected not only due to the operating pressure and traveller speed but also due to the variations in the wind throughout the duration of the run. Wind drift and droplet evaporation losses can be large if the sprinkler design or pressure produces a high percentage of very fine droplets [4]. This conforms the finding of present study.

Application efficiency

The application efficiency of 74% was quite good and high efficiencies are typically hard to obtain with mobile irrigator but it is high as compared to surface irrigation system which ranges from 45-65% [4]. Table 3 shows that, F values of travel speed are significant ($\rho < 0.01$) for application efficiency. This table showed F values of operating pressure are significant in $\rho < 0.01$ for application efficiency. The interaction between travel speed and operating pressure are also significant in $\rho < 0.01$.

Table.3. Variance analysis of application efficiency

Application efficiency			
Variables	*df*	*Mean Square*	*F*
Travel Speed (S)	*2*	*188.53*	*89.73***
Operating Pressure (P)	*2*	*60.99*	*18.97***
*S*P*	*4*	*49.15*	*11.84***
Total	*8*	*-*	*-*

***p is significant at 0.01 level.*

The graph is plotted between depths of water collected in the catch can and can spacing (Fig. 2). This graph shows 15% overlap and depth of water collected decreases from centre to periphery. The graph infers that depth of water applied is more at the centre of the field than at the field boundaries. Application efficiency takes into account losses such as spray drift, evaporation, runoff, deep drainage and application of water outside the target crop area. Of these factors, deep drainage and runoff are probably the largest causes of inefficiency and generally due to over irrigation. Because of the losses during application, water application efficiency is always less than 100% [4]. Higher rate of irrigation can result in runoff and erosion on soils that have a slow intake rate. Whenever more water is applied than the water requirement of the crop, water is wasted and efficiency is low. Raingun that was used covers an area of about 1 acre when operated at a pressure of 245 kPa but it covers only 0.7 acre at a pressure of 195 kPa. Reducing the pressure at the raingun increases average droplet size and therefore, potential soil compaction. Application rate may be increased, leading to increased runoff. The total amount of water applied is affected by lane spacing, sprinkler capacity and irrigator travel speed [3].

The crop spacing should be regular and separate lane should be provided for irrigator to travel and irrigate the field. If there is insufficient spacing or no provision of separate lane for irrigator to travel the crop damage will occur. The system had some difficulties like, being a pneumatic wheel it gets struck in the field when the field becomes wet, when the irrigated soil contains more clay content. When the clay content was high it caused slip of the wheel during wet condition and a layer of soil was adhering on the wheels, which lead to more force requirement to pull, causing sometimes drudgery.

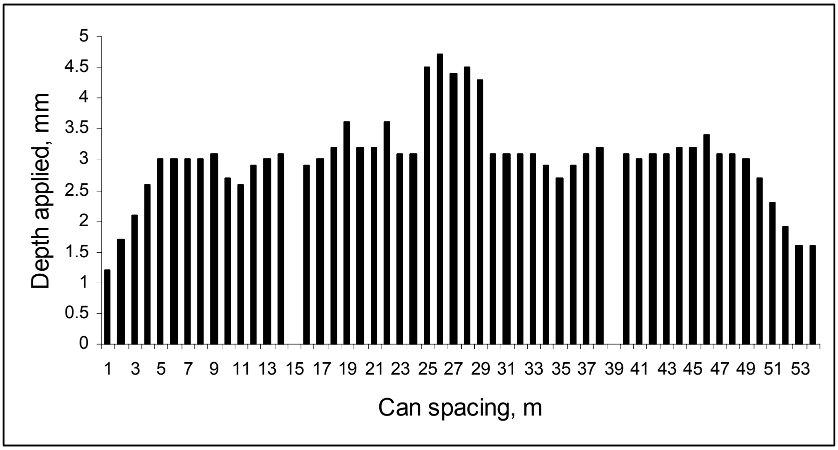


Figure 2. Combined distribution pattern

A half way rotating raingun viz. 180^o rotating type can be used instead of a full rotation raingun viz. 360^o rotating type which was used now. This can be done to enhance more complete coverage of the field.

CONCLUSIONS

The mobile irrigator which was developed found helpful in using the available water effectively with satisfactory value of application efficiency (74%), distribution uniformity (75%) and the time consumption was also acceptable. It is suitable to irrigate the dry land cultivated area or area needing supplemental irrigation. The height of the crop for which the system to be used should be short or medium height about 1.5 m. The height of the crop when increases above 1.5 m the irrigator cannot be used. This irrigator is difficult to move from field to field. It may be possible to substitute other types of irrigation systems, but for some farmers and some applications, the mobile irrigator is still the most economical machine when initial cost, operating cost and labour required are considered.

BIBLIOGRAPHY

[1] Claude, H., Pair, P.E. 1970. USDA-ARS-SWC Northwest branch, Mechanized Sprinkler Systems, their Applications and Limitations — What Next? CC-1 *Proceedings of the National irrigation symposium,* p. 10-13.

[2] Curtis, L.M., Tyson, T.W. 1988. *The Cable Tow Irrigation System: Operational, Energy and Planning Requirements,* p. 1-8.

[3] Evans, R., Sneed, R.E. 1996. Selection and Management of Efficient Self-Propelled Gun Traveler Irrigation Systems. *North Carolina Cooperative Extension Service* 4(3), p. 91-150.

[4] Irmak, S., Odhiambo, L.O., Kranz, W.L., Eisenhauer, E. 2011. Irrigation Efficiency and Uniformity and Crop Water Use Efficiency. University of Nebraska. Lincoln EC 732. p. 1-8. (http://extension.unl.edu/publications).

[5] Wigginton, D.W., Raine, S.R. 2007. Irrigation Water Use Efficiency in the Mary River Catchment: On-farm performance evaluations in the dairy sector. *National Centre for Engineering in Agriculture*, p. 17-26.

RAZVOJ I OCENA PERFORMANSI MOBILNOG UREĐAJA ZA NAVODNJAVANJE U SUVOM RATARENJU

Ravi Pandiselvam[1], Nawab Jan Amreena Jan[2] , Gurusamy Parthasarathi[3], Kunjurayan Rajesh[1], Ganapathy Kaveri[1]

[1] Poljoprivredni univerzitet Tamil Nadu, Institut za hranu i poljoprivredni inženjering, Coimbatore, Indija
[2] Poljoprivredni univerzitet Tamil Nadu, Institut za poljoprivrednu ekonomiku, Coimbatore, Indija

Sažetak: Ovao istraživanje je sprovedeno na Fakultetu za poljoprivrednu tehniku i Istraživačkom institutu Kumulur u Tamil Nadu, Indija. Mobilni uređaj za navodnjavanje je razvijen za efikasnu upotrebu dostupne vode u suvom ratarenju umesto dodatnog navodnjavanja. U slučaju dodatnog navodnjavanja smanjuje se efikasnost upotrebe i ujednačenost distribucije. To smanjuje i prinos i efikasnost korišćenja vode. Kako je cilj ovog istraživanja bio da razvije mobilni uređaj za navodnjavanje koj će biti lak i pogodan za ručno pomeranje tokom navodnjavanja. Ocena performansi (efikasnost navodnjavanja i ujednačenost distribucije) uređaja su testirani na suvom polju kukuruza. Rezultati su pokazali prihvatljivu efikasnost navodnjavanja od 74% i koeficijent distribucije od 75%. Brzina kretanja i radni pritisak bili su optimizirani na oko 2.1 $cm \cdot s^{-1}$ i 245 kPa. Sistem može biti upotrebljen za navodnjavanje kukuruza, kikirikija, mahunarki i sl. Za postizanje efikasnog navodnjavanja visina useva treba da bude do 1.5 m.

Ključne reči: *pokretni uređaj za navodnjavanje, ujednačenost distribucije, efikasnost primene, suvo ratarenje*

Prijavljen: *Submitted*:	22.02.2014
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	27.08.2014.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 63 – 71

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 63 – 71

UDK: 631.62

Originalni naučni rad
Original scientific paper

IMPACT ASSESSMENT OF DRAINAGE WATER MANAGEMENT IN SALT AFFECTED SOILS OF GODAVARI WESTERN DELTA ON A PILOT SCALE IN INDIA

Sidlagatta Vishnu Vardhan[1*], Chilamkurthy Sreenivas[2], Chinta Venkat Reddy[2], Pandraju Sreedevi[1]

[1]Acharya N.G. Ranga Agricultural University, Faculty of Agricultural Engineering and Technology, Hyderabad, Andhra Pradesh, India
[2]Acharya N.G. Ranga Agricultural University, Faculty of Agriculture, Hyderabad, Andhra Pradesh, India

Abstract: A.P. Water Management Project, Andhra Pradesh was planned with implementing various improved irrigation, drainage water management practices and is executed using object oriented project planning technique under financial assistance from FAO. Drainage is an effective tool in combating the negative effects of salinity and water logging. Five years of operational pilot research were conducted in farmer's fields of Kalipatnam pilot area by installing a sub-surface drainage (SSD) system with a drainage coefficient of 1 mm·day^{-1} to control the increasing levels of soil salinity levels in Godavari Western Delta of India on a pilot scale. There has been significant decrease in the soil salinity in the range of 33% in the pilot area through leaching of salts to the tune of 59 t·ha^{-1} from the system during 2005 - 2009. Productivity levels were increased by 15 - 25% in kharif season and 25 - 40% in rabi season. An economic analysis showed that SSD system is cost effective and benefit cost ratio was worked out be 3.3 with a payback period of 2.18 years with internal rate of return of 27.19%. Potential impact has been found significantly in soil quality, crop performance, improvement in family income, land value and gender issues were also addressed.

Key words: *Sub surface drainage system, drainage effluent, drainage coefficient, salt load, internal rate of return, leaching, seawater intrusion*

[*] Corresponding author. E-mail: vishnuvardhans@yahoo.com

The authors express their gratitude to Food and Agricultural Organization (FAO), Rome for funding the A.P. Water Management Project and Dr. J. Boonstra, Chief Technical Advisor, Other consultants from Alterra-ILRI, Wageningen University, The Netherlands, for technical guidance provided.

INTRODUCTION

The sustainability of irrigated agriculture is under threat due to widespread occurrence of water logging and soil salinity. Drainage can be viewed as the "price to pay" for the sustainability of irrigated agriculture if considered in a holistic approach in the framework of integrated in water management improvement strategies and as part of rural development at large. Drainage is an effective tool in combating the negative effects of salinity and water logging. Sub-surface drainage system is the only option to realize the full potential of crop production by creating artificial drainage to control the soil salinity and managing the water table below the root zone. Rapid irrigation development has resulted in a range of environmental problems. Many of these relate to salinity in soil and/or water resources, often associated with a lack of drainage facilities. It is estimated that nearly 8.4 million ha of irrigated area in India is affected by soil salinity and alkalinity, of which about 5.5 million ha is also waterlogged [5]. An area of 40036 Ha of Godavari Western Delta (GWD) in Andhra Pradesh is saline prone and water logged due to high intensity rainfall with deficiency of drainage capacity, unfavorable out-fall condition, obstructions in drainage stream and tidal actions [2]. In order to suggest suitable reclamation technology for combating twin problems of water logging and soil salinity, a Kalipatnam pilot area at the tail end of Kalipatnam Main Channel (KMC) distributory of the Gostanadi & Velpuri (G&V) Canal of Godavari Western Delta, India, comprising of farmer's field to carry out operational research was selected and suitable interventions were designed, constructed and practiced and its potential impact on the society were analyzed.

MATERIAL AND METHODS

For identifying the problems in the pilot area, Participatory Learning & Action (PLA) was conducted to the farmers of the Kalipatnam pilot area in association with the local Non-Governmental Organization (NGO).

Major problem identified in the pilot area was lower crop yields that was caused due to number of reasons viz., drainage congestion due to tidal fluctuations of salt stream, induced soil salinity due to sea water ingress, repeated transplantations, improper outlet conditions and insufficient carrying capacity of drains. The recommendations of the Indo-Dutch Network Project were followed for the installation of the sub-surface drainage system for salinity control in canal commands [6]. Various details of pre-drainage investigations in the pilot area were presented in Tab. 1. Based on these pre-drainage investigations composite type of layout was selected to install the closed subsurface drainage system. On western side of collector pipe, 7 laterals of about 225 m were installed and on eastern side 7 laterals of about 275 m lengths were installed at a spacing of 50m. The design characteristics for the SSD system in Kalipatnam were presented in Tab. 2 and design layout is presented in Fig 1.

Recommended design characteristics were evaluated for installation of sub-surface drainage system in the pilot area [7] [8]. Daily observations on irrigation and drainage water quality and quantity were recorded. Sub surface drainage effluent quality and quantity were also recorded on daily basis. Water table fluctuations and ground water quality were recorded on fortnightly basis.

Table 1. Pre-drainage investigations of the pilot area

S.No.	Parameters	Results
1	Hydraulic conductivity	0.33 $m \cdot day^{-1}$
2	Average annual Rainfall	1246 mm
3	Evaporation	1430 mm
4	Drainage coefficient	1 $mm \cdot day^{-1}$
5	Depth to water level	0.0 – 0.9 m
6	Depth to impervious layer	7.0 m
7	Irrigation water EC	Up to 0.4 $dS \cdot m^{-1}$
8	Tidal range in Upputeru	0.0 to 0.9 m
9	EC of soil	4.0 to 16.3 $dS \cdot m^{-1}$
10	Soil type	Saline Sodic
11	Soil texture	Loamy sand to sandy clay
12	SAR	14.88 to 21.14
13	ESP (%)	15.47 to 23.03
14	Cropping pattern	Rice – Rice- Fallow
15	Method of irrigation	Flooding
16	No. of Farmers	28
17	No of land holdings	36

Table 2. Salient features of design parameters of sub-surface drainage system

Drain spacing	50m
Drain depth	0.8m
Slope of the Collector line	0.03%
Slope of field drains	0.1%
Envelope	Nylon mesh
Pipe material For laterals For collector	 Corrugated PVC (80mm diameter) Rigid PVC (160 mm diameter)
Design discharge	1$mm \cdot day^{-1}$
Drainage outlet condition	Pumped outlet of capacity 9.5 $l \cdot s^{-1}$

During every summer, in-situ hydraulic conductivity measurement were taken and soil samples were collected and analyzed for their physico-chemical properties. Yields patterns were recorded on grid basis (100 X 100 m interval for entire pilot area) and farmers were interviewed for yield assessment. Average of both were calculated for yield estimation. Various improved water management practices in the frame work of IWRM in different pilot area scenario have been monitored using different logical indicators to draw a meaningful conclusion for the long term effects of interventions. The long term strategy is to stimulate agricultural growth and promote rural development through improved water and land management, enhanced efficiency of irrigation and drainage networks, increased attention to environmental protection and improved rural infrastructure.

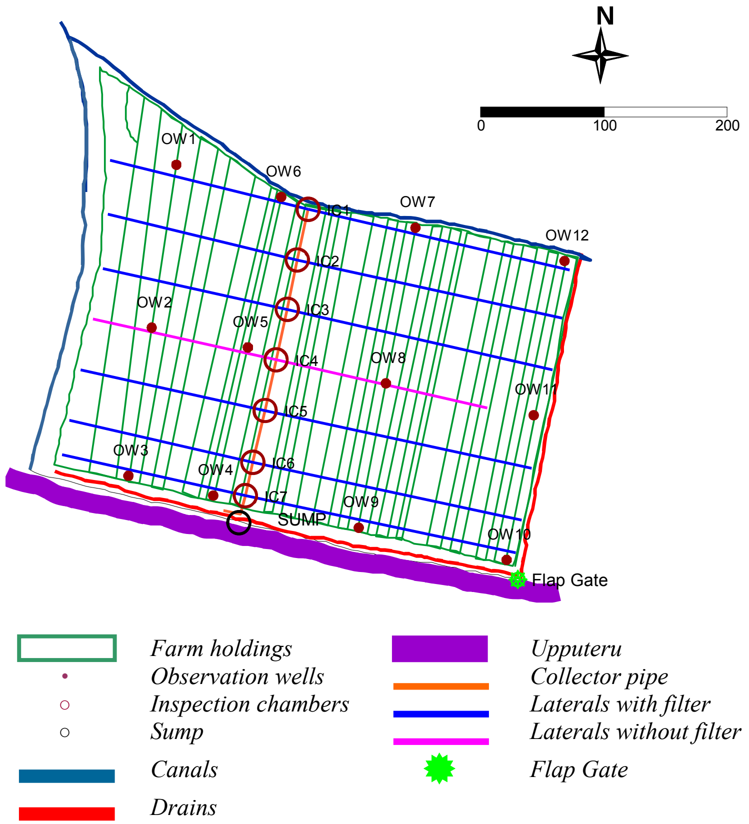


Figure 1. Layout of sub-surface drainage system in Kalipatnam Pilot area

RESULTS AND DISCUSSION

The recorded data was compiled and analyzed for quantitative assessment of impact of sub-surface drainage system. The impact of the system on pilot area was observed through various means viz., soil hydrological parameters, desalinization of soil profile, relation between drain volume and drain water salinity, crop performance, financial viability, change in land value and changes in the socio-economic aspects of the farmers.

Crop performance

Before installation of sub surface drainage system in the pilot area, the cropping pattern followed was paddy-paddy-fallow. The same pattern has been followed till now. The productivity patterns usually vary from kharif to Rabi seasons due to vagaries of the availability of photosynthetic active radiation from the sunlight. Rabi yields are generally higher owing to long duration of solar radiation. It was estimated that there was a 46.05 per cent increase in the yields during Kharif season (3.8 - 5.5 $t \cdot ha^{-1}$) and a 50 per cent increase in yields during Rabi season (5.3 - 8.0 $t \cdot ha^{-1}$). Yield increase was mainly attributed due to reduction in soil salinity in the root zone due to leaching process enhanced by sub-surface drainage system. Similar positive effect on crop yields were obtained in paddy, sugar cane, kharif fodder, sugar beet and tobacco crop through the subsurface drainage technology and yields were increased by 46, 49, 50, 56, 43 and 23 per cents respectively [3].

Soil quality

The impact of sub-surface drainage system on soil salinity has been presented in Tab. 4. The data on soil salinity levels of before the installation of SSD (summer, 05) and one year, two years and four years (summer, 06, 07, 08 and 09) after installation of Sub surface drainage system from the 48 grid points at four different depths (0-15 cm, 15- 30 cm, 30-60 cm and 60-100 cm) have been analyzed presented in Tab. 3.

A perusal of data indicated that there was considerable reduction in soil salinity in the pilot area. ECe has been lowered two year after installation thus showing overall effect was positive. ECe of soils were reduced by 20.15 per cent in surface soil and 28.58- 41.24 per cent in sub surface soil. The depth wise reduction in soil salinity indicated that upper layers were reclaimed at faster rate (7.59 to 6.70 $dS \cdot m^{-1}$, 11.70 %) than the deeper layers (9.62 to 8.77 $dS \cdot m^{-1}$, 8.80 %) after one year of installation of SSD as salt encrustation at the top soils were leached out due to sub-surface drainage.

Financial viability

Economic viability of a closed surface drainage system is of major consideration for large-scale implementation of the project in the drainage sub basin and/or basin level. The techno-economic evaluation was carried out by A.P. Water Management Project [8]. The analysis showed that benefit cost ratio for the project worked out to be 3.32 with average annual return per rupee of investment to be 0.46. The SSD system at Kalipatnam had a capital investment of Rs. 0.479 million has the capacity to earn a rate of return of 27 per cent, which is higher than the opportunity cost of capital or market rate of interest and pay back period of 2.18 years proving that technological intervention is financially feasible, economically viable and cost effective.

Socio-economic impact of drainage interventions

The socio-economic including gender studies were conducted in the drainage pilot area. All the farmers including the women have participated in the surveys.

Farmers attitude to drainage

Post project evaluation to assess the farmer's view on drainage technology revealed that all the respondents were convinced and agreed that the drainage technology is an effective technology to solve the problems of water logging and soil salinity leading to increase in yield, increase in cropping intensity and switchover from fish culture to paddy cultivation. Farmers are aware that they had an increased access to credit. Farmers are able to take loans from banks and cooperative societies as they have got repayment capacity as they have assured crop for at least one season. This fact was confirmed from the responses during interactions with the FAO Evaluation Team for evaluating project performance [1].

Knowledge on adoption of improved water management practices

The majority of the farmers have vast experience in irrigated agriculture. Farmers have gained hands on experience in water management aspects and awareness levels on various aspects like Crop management, Soil and water management, Identification of pests and diseases, Use of plant protection chemicals, Preparation of botanical extracts and Rodent control improved significantly during the tenure of the project with capacity building programs of APWAM Project in pilot areas like trainings and kalazathas.

Farmers input to implement and maintain drainage systems

- Farmers are willing to maintain the installed drainage systems on their own cost.
- Farmers are of the opinion that Government should support installation of sub-surface drainage systems in the form of subsidies. They are however, willing to actively participate in future drainage projects either by meeting a part of the cost by the way of providing labour for the installation.

Secondary benefits of drainage project interventions

The reclamation of water logged and salt affected lands besides resulting in direct benefits and sustainability of irrigated agriculture, also helps to achieve the following benefits.

Market value of land and social status

The land reclamation also leads to improvement in the social status of the farmers with improvement in land productivity. There was considerable improvement in asset value of the land after drainage intervention. Though, there has been general increase in land appreciation, still there is a gap in the market value of land in drainage pilot area and non pilot area to a tune of Rs.0.30 million·ha^{-1}.

Employment generation

Reclamation program generates employment opportunities both during drainage execution and during post drainage period under crop production program. It generated as many as 32 man-days per ha during installation of drainage systems. Further, the intervention has also offered an annual employment of 107 man-days per ha during kharif and 125 man-days per ha during rabi on reclaimed land under crop production activities.

Gender issues

The following are the important observations made on this aspect:

- Although women are actively involved in farming activities, they are not so much involved in agriculture and agricultural water management.
- Women are aware of the thing that their increase annual incomes are due to drainage interventions in their fields.

- Women are also aware that their family expenditure had rose from pre-drainage period to post-drainage period owing to improved land productivity and increased annual cropping intensity.

Women are aware that part of their extra earnings were spent on improved diet for better health, better medical facilities, purchase of assets like oil engines, motor cycles, sprayers, etc, repair of existing houses, rearing of milk animals and chicks, education and marriage activities.

Table 3. Impact assessment of sub-surface drainage technology on soil salinity and productivity levels in Kalipatnam pilot areas

S.No.	Pre-drainage situation		End of 1st year	End of 2nd year	End of 3rd year	End of 4th year
1.	Soil salinity ($dS \cdot m^{-1}$) 0-15 cm	4.03-16.35 (7.59)	3.44-10.86 (6.49)	3.33-11.20 (6.06)	2.09-11.27 (5.08)	2.97-9.50 (5.51)
2.	Soil salinity ($dS \cdot m^{-1}$) 15-30 cm	6.06-27.50 (9.62)	4.06-13.75 (8.77)	2.93-12.15 (6.87)	2.93-9.48 (5.24)	2.90-13.0 (6.13)
3.	Kharif yield ($t \cdot ha^{-1}$)	3.8	4.4	5.0	5.5	5.3
4.	Rabi yield ($t \cdot ha^{-1}$)	5.3	8.0	7.4	7.9	7.1

Table 4. Comparison of market value of land in pilot and non-pilot areas

Pilot area	Pre-drainage (Rs. million$\cdot ha^{-1}$)	Post drainage (Rs.million$\cdot ha^{-1}$)	
	Pilot/Non pilot	Pilot	Non pilot
Kalipatnam pilot area	0.25	1.5	1.2

CONCLUSIONS

Based on the analysis of the study, the following conclusions were drawn:

1. Sub-surface drainage technology has been very instrumental in achieving sustainable agricultural productivity levels in the saline-sodic soils of Godavari Western Delta that were badly affected by salinity and waterlogged situations.
2. ECe of soils were reduced by 20.15 per cent in surface soil and 28.58- 41.24 per cent in sub surface soil indicating that desalinization of soil profile was taken place.
3. The productivity levels of paddy were increased by 46% in kharif season and 50% in rabi seasons.
4. Sub-surface drainage technology is financially feasible, economically viable and cost effective with pay back period of 2.18 years.
5. Better rural development through improved water and land management, enhanced efficiency of irrigation and drainage networks, increased attention to environmental protection and improved rural infrastructure was achieved.

BIBLIOGRAPHY

[1] Anonymous. 2008. *Report of FAO Evaluation Mission A.P. Water Management Project* (GCP/IND/176/NET).

[2] Anonymous. 2001. *A Technical report by National Bureau of Soil Survey and Land Use Pattern*, Nagpur.

[3] Azhar, A.H., Alam, M.M., Rafiq, M. 2005. Agricultural Impact assessment of sub-surface drainage projects in Pakistan – Crop Yield Analysis. *Pakistan Journal of Water Resources*, Vol 9(1), January-June, 2005/1.

[4] Christen, E.W., Ayar, J.E. 2001. *Sub-surface drainage system-Design and Management in Irrigated agriculture: Best Management Practices for reducing drainage volume and salt load.* Technical report 38/01, CSIRO, Land and Water, Griffith, NSW. P: 67-69

[5] Ritzema, H., Satyanarayana, T.V., Raman, S., Boonstra, J. 2008. Sub-surface drainage to combat water logging and salinity in irrigated lands in India: Lessons learned in farmer's fields. *Agricultural Water Management*, Vol 95(3), 179-189.

[6] Sreedevi, P, Ganesh Babu, R., Sreenivas, Ch. 2008. Evaluation of Design Characteristics to install Sub-surface drainage system at Kalipatnam Pilot area of Godavari Western Delta. *The Journal of Research ANGRAU*, Vol 36(1):1-5.

[7] Satyanarayana, T.V., Lakshmi, G.V., Srinivasulu, A., Hanumanthaiah, C.V., Ratnam,M., Hemakumar, H.V. 2002. *Drainage and Water Management for Salinity Control in Canal Commands.* A Comprehensive report of Research Achievements of Bapatla Network Center, Indo-Dutch Network Operational Research Project, Acharya N.G. Ranga Agricultural University, Bapatla.

[8] Vishnushankar Rao, D., Satyanarayana, T.V., Sridevi, P., Sreenivas, Ch., Sambasiva Rao, P. 2006. *Techno-Economic Evaluation of Sub-surface Drainage Technologies in Godavari Western Delta Saline-Alkali and Water logged Environment in Techno-Economic Evaluation of sub-Surface Drainage Technologies*, Acharya N.G. Ranga Agricultural University, A.P. Water Management Project, Bapatla. P: 25-52.

[9] Vishnu, Vardhan S, Sreenivas Ch, Venkata, Reddy, C., Muralikrishna, T. 2009. *Improving sub-surface Drainage System* – A case study. In Proc. Of 60th International Executive Council and 5th Asian Regiojnal Conference on " Improvement in Efficiency of Irrigated Projects through Technology Up gradation and Better Operations and maintenance" held during 6-11 December, 2009, New Delhi. P: 215

PROCENA UTICAJA UPRAVLJANJA ODVEDENOM VODOM NA SLANIM ZEMLJIŠTIMA NA OGLEDNOM POLJU DELTE ZAPADNOG GODAVARI U INDIJI

Sidlagatta Vishnu Vardhan[1], Chilamkurthy Sreenivas[2], Chinta Venkat Reddy[2], Pandraju Sreedevi[1]

[1]Poljoprivredni univerzitet Acharya N.G. Ranga, Fakultet za poljoprivrednu tehniku i tehnologiju, Hyderabad, Andhra Pradesh, Indija
[2] Poljoprivredni univerzitet Acharya N.G. Ranga, Poljoprivredni fakultet, Hyderabad, Andhra Pradesh, Indija

Sažetak: A.P. projekat upravljanja vodom u Andhra Pradesh bio je planiran sa primenom različitih unapređenih postupaka navodnjavanja i drenaže vode i izveden je uz finansijsku pomoć FAO. Drenaža je efikasno sredstvo za borbu protiv negativnih efekata saliniteta i zadržavanja vode. Pet godina je operativno pilot istraživanje sprovođeno na parcelama farmera u oblasti Kalipatnam postavljanjem sistema pod-površinske drenaže sa koeficijentom drenaže od 1 mm na dan, radi kontrole rastućih vrednosti saliniteta zemljišta na oglednom polju u zapadnoj delti Godavari. Postignuto je značajno smanjenje saliniteta zemljišta od 33% na oglednom polju ispiranjem soli iz sistema sa 59 $t \cdot ha^{-1}$ tokom 2005 – 2009. Produktivnost je povećana za 15-25% u kharif sezoni i 25-40% u rabi sezoni. Ekonomska analiza je pokazala da je ovaj sistem drenaže i finansijski efikasan, a odnos prihoda i troškova je bio 3.3, sa periodom otplate od 2.18 godina i internom ratom od 27.19%. Značajan je bio i potencijalni uticaj na kvalitet zemljišta, osobine useva, unapređenje porodičnih prihoda i vrednost zemljišta.

Ključne reči: *Pod-površinski system drenaže, drenažni odliv, koeficijent drenaže, slain talog, interna rata, ispiranje, morska voda*

Prijavljen: *Submitted*:	27.3.2014
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	12.08.2014.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 73 – 83

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 73 – 83

UDK: 656.137:[629.048.8:621.327.54+621.382.2

Originalni naučni rad
Original scientific paper

UŠTEDA ENERGIJE KOD POLJOPRIVREDNIH TRAKTORA PRI UPOTREBI RAZNIH VRSTA SIJALICA

Zlata Bracanović[1*], Velimir Petrović[1], Branka Grozdanić[1], Slobodan Janković[2]

[1]*Institut IMR-a, Beograd,Srbija*
[2]*Tehnički fakultet -Mihajlo Pupin, Zrenjanin, Srbija*

Sažetak: Napredne tehnologije doprinele su modernizaciji traktora, omogućile rukovaocu traktora efikasnost, komfornost, sigurnost u radu i kretanje u saobraćaju. Halogene sijalice i LED moduli, kao sastavni delovi za inoviranje svetlosnih uređaja kod traktora, odaju veću količinu svetlosti bez senki i blještavosti. LED module karakteriše mala nominalna snaga i toplotno emitovanje, a zbog svog sastava nisu toksični.

Posmatrajući karakteristike i namenu standardnih sijalica, koje se koriste kod svetlosnih uređaja poljoprivrednih traktora, data je odgovarajuća zamena istih sa halogenim sijalicama i LED modulima. Analizirana je minimalna i maksimalna potrošnja energije za šest modela poljoprivrednih traktora proizvođača IMR-a, pri upotrebi različitih sijalica. Date su neke moguće varijante uštede energije kod posmatranih modela traktora, ostvarene zamenom standardnih sijalica na svetlosnim uređajima i instrument tabli traktora.

Prema zvaničnim podacima o broju poljoprivrednih traktora vezanih za popis poljoprivrede, u Srbiji ima oko 410.894 dvoosovinskih traktora. Ako se predpostavi, da je 60 % traktora od ukupno registrovanih traktora proizvodnja IMR-a, dolazimo do podatka o mogućoj uštedi energije za neki projektovani vremenski period.

Ključne reči: *traktor, LED moduli, energija.*

UVOD

Elekreo oprema kod traktora je sastavni deo ukupnih elektro sistema koji kontrolišu, upravljaju i na taj način održavaju isparvnost namenskih funkcija traktora. Upotreba

[*] Corresponding author. E-mail: zlatabracanovic@yahoo.com

nekih naprednih tehnologija kod svetlosne elektro oprema traktora doprinela je ukupnom kvalitetu spoljnjih i unutrašnjih svetala, sigurnoj indikaciji svih izvršnih funkcija traktora kao i smanjenoj potrošnji energije.

Cilj ovog rada je ušteda energije kod poljoprivrednih traktora, odnosno kako i na koji način obezbediti manju potrošnju energije kod upotrebe svetlosne opreme traktora a pri tom dobiti kvalitetnije i stabilnije osvetljenje. Svaka funkcija traktora ima odgovarajuću svetlosnu indikaciju odnosno sijalicu, pa u zavisnosti od namene razlikuje se deklarisana snaga sijalice. U ovom radu ukazuje se na vrstu i snagu sijalica potrebnih za svetlosne uređaje traktora, na potrošnji energije koju ostavruju svojim svetlosnim efektima, kako bi rad traktora bio ispravan i rukovaocu traktora omogućena sigurnost u radu kao i kretanje u saobraćaju.

Kako sve obične sijalice deklarisane snage P(W) imaju adekvatnu zamenu sa halogenim sijalicama i LED moudulima, znatno manje nazivne snage P(W), može se videti kolika je razlika u potrošnji energije. Sve standardne sijalice podležu direktivi EEC od strane Evropske unije i EN standarda za Evropu nizom pravilnika ECE R. za kategorije T. Halogene sijalice i LED moduli su definisani međunarodnim standardima: EN60598 (IP-stepen zapivenosti), EN62262 (IK-stepen otpornosti) [1].

Za rukovaoca poljoprivrednih traktora veoma je značajno da ponuđene kombinacije halogenih sijalica i LED modula, odaju veću količinu svetlosti, manju blještavost a da pritom je troše manje energije [2]. Ovaj rad transparentano prikazuje utrošene energije za posmatranih šest modele poljoprivrednih traktora proizvođača IMR-a, kao i detaljnu analizu uštede energije za svaki model. Istovremeno, ušteda energije kod traktora pozitivno se odnosi i na produžen vek trajanja akumulatora, odnosno na povećanje broja uključenja motora.

Na bazi činjenica o potrošnji energije svetlosnih uređaja kod poljoprivrednih traktora, a prema broju registrovanih traktora u Srbiji, tabelarno su prikazani projektovani podaci o uštede energije za vremenski interval od pet godina.

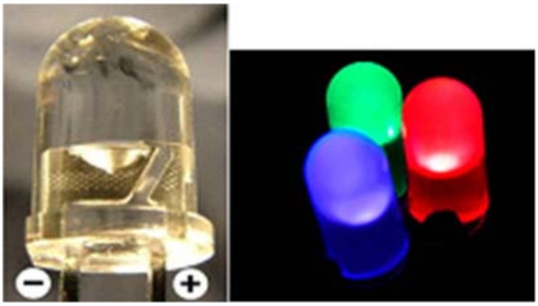
MATERIJAL I METODE RADA

Sijalice su sastavni deo svetlosnih uređaja poljoprivrednih traktora: pokazivači pravca, poziciono svetlo, osvetljenje kabine, svetlo upozorenja, svetlo aktivne kočnice, parkirno svetlo, osvetljenje registarske tablice, prednji i radni far. Takođe, sijalice kao indikacija kod prekidača, tastera i kontrolnomernih instrumenata su pokazatelji ispravnosti funkcionisanja sistema merenja, kontrolisanja električnih i nelektričnih veličina.

Kako novi zakonski propisi nalažu neprekidnu uključenost prednjih svatala odnosno farova traktora, u toku rada i u saobraćaju, potrošnja energije kod poljoprivrednih traktora je povećana. Imajući to u vidu, ovaj rad je obuhvatio pregled svih postojećih svetlosnih uređaja kod šest modela poljoprivrednih traktora proizvođača IMR-a. Analiza je obuhvatila sve standardne sijalice koje se koriste kod pomenutih traktora i njigovu odgovarajuću zamenu sa halogenim sijalicama i LED modulima.

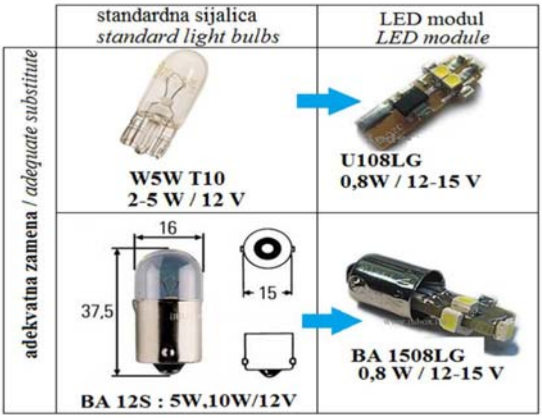
LED moduli su konstruisani od nekoliko svetlećih SMD dioda (LED:Light-emiting diode) ravnomerno raspoređenih u zavisnosti od namene, koje su izrađene po RoHS standardu. Ovaj standard se odnosi na sastav materijala, koji se koristi za izradu dioda, znači da u sebi ne sadrži: Olova (Pb-Lead), žive (Hg), cadmiuma (Cd), šestovalentnog hroma (CrVI), polybrominated biphenyls (PBB) i polybrominated diphenyl ethers (PBDE) materije štetne po okolinu [3].

Da bi se emitovala svetlost odnosno svetlosni talasi kod svetlećih dioda dolazi do katodne luminiscencije elektona ili grupe elekrona koje usmerenim kretanjem u pravcu elektroda različitih napona prelaze sa višeg na niži energetski nivo. Talasna dužina emitovane svetlosti, a samim tim i boja svetlosti zavisi od prirode grupa elekrona formiranog p-n spoja. Izbor poluprovodničkog materijala dioda određuje boju svetlosti. Novi materijali su omogućili da diode proizvode svetlost u boji, tako što se izgrađeni p-n spoj prekriva emisionim talogom od legura metala IIIa i Va grupe periodnog sistema elemnata: aluminijum-Al; galijum-Ga; arsenid-As; fosfid-P; azot-N; indijum-In. Štampane ploče su lemljene bezolovnim kalajem. Diode imaju različito polarisane krajeve, plus (+) i minus (-). To znači da ako se pogrešno postavi u ležište neće sijati, ali neće pregoreti jer postoji zaštita od pogrešnog spajanja. Na slici 1. dat je opšti izled svetlećih dioda i kao primer izgled dioda sa odavanjem svetlosti nekih boja.



Slika 1. Izgled LED – svetleće diode

Figure 1. Appearance LED - light emitting diode



Slika 2. Primeri nekih odgovarajućih zamena standardne sijalice sa LED modulom

Figure 2. Examples of some appropriate replacement of standard light bulbs with LED module

Kako bi se zamena standardnih sijalica sa LED molulom bila adekvatna sa svim neophodnim karakteristikama, data su dva transparentna primera odgovarajuće zamene sijalica na Sl. 2.

Porizvođači sijalica su prilagodili proizvodnju halogenih sijalica kao i LED modula tako, da je moguća ugradnja istih na postojeća sijalična gnezda običnih standardnih sijalica. Na ovaj način, proizvođačima i korisnicima poljoprivrednih traktora ostavlja se mogućnost izbora ugradbenih sijalica kod svetlosnih uređaja traktora. U Tab. 1. navedene su karakteristike standardnih sijalica i LED modula, čiji izgled je dat na Sl. 2., neophodnih za ostvarivanje odgovarajuće zamene.

Tabela 1. Prikaz karakteristika nekih standardnih sijalica i LED modula
Table 1. Representation of the characteristics some standard bulbs and LED modules

Vrsta i oznaka sijalice/modula *Species and designation bulbs / modules*	Standardna sijalica *Standard light bulbs*		LED modul *LED module*	
	BA12S	W5WT10	BA1508LG	U108LG
Karakteristike / *Characteristics*				
Prečnik / *Diameter* d (mm)	15	10	12	9
Visina / *Height* h (mm)	37	25	37	26
Napon / *Voltage* U (V)	12	12	12÷15	12÷15
Snaga / *Power* P(W)	5÷10	2÷5	0,8	0,8
Ugao osvetljenja / *Angle of illumination* β (°)	180	180	360	360

Kao što se videti iz priložene Tab. 1. karaktristike standardnih sijalica i LED modula bitnih za ugradnju su podudarne i zadovoljavaju potrebne gabaritne dimenzije. Napajanje sijalica i LED modula je identično.

Navedeni LED moduli u tabeli 1. su konstruisani sa osam SMD dioda, ravnomerno raspodeđenih pod uglom α=120 (°), što doprinosi ekstra osvetljenju za ugao osvetljenja β=360 (°), sa dodatom pozicijom osvetljenja napred. Namena i upotreba ovih LED modula, je kod prednje i zadnje pozicije, unutrašnjeg osvetljenja i instrument table. Zastupljene boje kod LED modula su : bela, plava, crvena, zelena i žuta [4]. Za ugradnju pomenutih LED modula i standardnih sijalica koristi se isto sijalično gnezdo, što se i vidi prema datim podacima u Tab. 1.

Na osnovu predhodno rečenog, moguće je izvršiti zamenu svih standardnih običnih sijalica kod svetlosnih uređaja traktora sa odgovarajućim halogenim sijalicama i LED modulima. Svetlosni uređaji na poljoprivrednom traktoru prema svojoj funkciji i nameni imaju definisanu pripadajuću sijalicu sa karakteristikama koje podrazumevaju: oblik (prečnik i dužina), snagu, ugao i boju osvetljenja. U skladu sa navedenim karaktristikama formirana je Tab. 2. sa akcentom na naminalnu snagu sijalica.

U Tab. 2. transparentno su prikazani svetlosni uređaji traktora sa naznačenim snagama P(W) za pripadajuće obične standardne sijlice. Prema navedenoj nominalnoj snazi standardene sijalice, data je odgovarajuća zamena sa halogenim sijalicama i LED modulima sa naznačenom nominalnom snagom P (W). Kao što se vidi u tabeli 2, zamena sijalice za neke svetlosne uređaje, moguće je ostvariti upotrebom nekoliko ponuđenih kombinacija LED modula sa različitim nominalnim snagama. Na osnovu date minimalane i maksimalne snage P (W) za neke LED module, u daljem radu biće analizrana ukupna svetlosna energije pri upotrebi minimalane (P_{min}) i maksimalne (P_{max}) definisane za nominalne snage LED modula.

Tabela 2. Adekvatna zamena sijalica za svetlosne uređaje kod poljoprivrednih traktora
Table 2. Adequate replacement bulbs for lighting devices for agricultural tractors

Svetlosni uređaji na traktoru *Light equipment on a tractor*	Nominalna snaga sijalica za svetlosne uređaje traktora *Nominal power of the bulbs for lighting devices tractor* P (W)		
	Standardna sijalica *Standard bulb*	Halogena sijlaica *Halogen bulb*	LED modul *LED module*
Prednji farovi *The head lights*	45/50	H4 65/60	
Pokazivač pravca *Direction indicator*	21		1,5 2 3
Poziciono svetlo *Position lights*	10		0,25 0,8
Prednja radna svetla *Front working lights*	55	H1 55	
Osvetljenje kabine *Cabin lighting*	5		0,25 0,8
Pokazni instrumenti *Indicating instruments*	5		0,2 0,28 0,4 0,56 0,6
Svetlo upozorenja *Warning light*	55	H1 55	0,2 0,28 0,4 0,56 0,6
Zadnje radno svetlo *Rear working light*	45	H3 55	
Svetlo aktivne kočnice *The active brake light*	21		1,5 2 3
Parkirno svetlo *Parking lights*	21		1,5 2 3
Osvetlj. registarske tablice *License plate lighting*	10		0,25 0,8

Ko što se vidi u Tab. 2. za svetlosne uređaje: prednji farovi, prednja radna svetla, svetlo upozorenja i zadnja radna svetla predložena je zamena sa halogenim sijalicama. Za svetlosne uređaje: pokazivač pravca, poziciono svetlo, osvetljenje kabine, pokazni instrumenti, svetlo upozorenja, svetlo aktivne kočnice, parkirno svetlo, osvetljenje registarske tablice predložena je zamena sa LED modulima sa nekoliko mogućih kombinacija. Upotrebom podataka za nominalne snage LED modula izračunata je minimalna snaga P_{min} (W) i maksimalna snaga P_{max} (W), a odnose na ponuđene kombinacije u Tab. 2., u zavisnosti od svetlosnog uređaja traktora. Na osnovu izračunate snage svetlosnih uređaja može se doći do podatka o potrošenoj energiji za šest modela traktora, koja će bite izračunata sa zamenom sijalica na inastrument tabli kao i bez zamene sijalica kod instrument table traktora.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Upotrebljavajući podatke date u Tab. 2. za nominalne snage standardnih i halogenih sijalica kao i LED modula, kako i prema broju svih ugrađenih sijalica kod svetlosnih uređaja traktora, izračunate su ukupne snage svetlosnih uređaja za šest modela poljoprivrenih traktora, što je prikazano u Tab. 3. Kako je instrument table traktora izložena jakim sunčevim zracima koji pod nekim uglom umanjuju preglednost instrument table rukovaocu traktora, data je mogućnost izbora zamene sijalica na instrument tabli traktora [5].

Snaga sijalica svetlosnih uređaja traktora koja obuhvata zamenu svih standardnih sijalica kod svetlosnih uređaja traktora i sijalica na instrument table traktora obeležena je sa P_{sr1} (W), a izračuanta je po formuli (1).

$$Psr1 = (P max1 + P max1) : 2 \qquad (1)$$

Snaga sijalica svetlosnih uređaja traktora koja podrazumeva zamenu standardnih sijalica svetlosnih uređaja traktora bez sijalica na instrument table, obeležena je sa oznakom P_{sr2} (W) a računa se po formuli (2).

$$Psr2 = (P max2 + P max2) : 2 \qquad (2)$$

Tabela 3. Ukupna snaga sijalica svetlosnih uređaja za razne modela traktora proivzođača IMR-a
Table 3. Power lamp lighting fixtures for various models of tractors manufacturers IMR

Redni br. / *Order. no.*	Modeli traktora *Models of tractors*	Ukupna snaga sijalica kod svetlosnim uređajima traktora sa: *Total power of the lamps in lighting devices tractor with:* P (W)		
		Standardnim sijalicama *Standard bulbs* P_{sta}	Halogenim sijalicama i LED modulima *Halogen lamps and LED modules*	
			Sa instrument tablom *With dashboard* P_{sr1}	Bez instrument table *No dashboard* P_{sr2}
1	R47	434	314	326
2	R50 DV	447	312	335
3	R 60 transporter	453	317	342
4	R65	607	424	438
5	R65-12BS DV	672	475	549
6	R110-DV turbo	837	544	688

Kao što se može videti iz navedene tabele ukupna snaga standardnih sijalica svetlosnih uređaja traktora, obeležena sa Psta(W), je veća u odnosu na moguće zamene sijalica ostvarene upotrebom halogenih i LED sijalica, a razlikuje se u zavisnosti od modela traktora.

Kako bi se izračunala potrošnja energije upotrebom svetlosnih uređaja traktora odnosno uvidela moguća ušteda energije, pored navedenog o sijalicama i odgovarajućoj zameni, sagledani su ostali uticajni parametri. Na osnovu činjenica i testova zabeleženo je da traktor radi otprilike 420 (h) časova godišnje [6]. Od toga 60% odlazi na transport gde su zastupljeni svi signalni i svetlosni uređaji a 40% je rad u njivi gde nije potrebno stalono uključivanje prednjih i pozicionih svetala [7].

U tabeli 4. prikazana je potrošnja energije za razne modele traktora i obeležena je sa A(kWh), i prikazana je za period od godinu dana. Potrošnja energije svetlosnih uređaja traktora data je pri upotrbu sa standardnim sijalicama i obeležena je Asta (kWh). Potrošnja energije koja je ostvarena putpunom zamenom standardnih sijalica sa halogenim sijalicama i LED modulima obeležena je Asr1(kWh). U slučaju gde je izvršena delimična zamen standardnih sijalica kod svetlosnih uređeja odnosno bez zamene sijalica na instrument table, potrošnja energije je obeležena sa Asr2 (kWh).

Tabela 4. Potrošnja energije svetlosnih uređaja kod raznih modela traktora
Table 4. Energy consumption of lighting fixtures in a variety of models of tractors

Modeli traktora *Models of tractors*		Potrošnja energije svetlosnih uređaja traktora sa raznim sijalicama *Consumption of light tractor unit with a variety of bulbs* *A* (kWh)					
		Stand. sijalice Standard bulbs A_{sta}		Sa instr. tabl. From dashboard A_{sr1}		Bez inst. tabl. *No dashboard* A_{sr2}	
		1 god. *1 year*	5 god. *5 years*	1 god. *1 year*	5 god. *5 years*	1 god. *1 year*	5 god. *5 years*
1	R47	182,28	911,4	131.88	659,4	136,92	684,6
2	R50 DV	187,74	938,7	131.04	655,2	140,70	703,5
3	R 60 transporter	190,26	951,3	133.14	665,7	143,64	718,2
4	R65	254,94	1274,7	178.08	890,4	183,96	919,8
5	R65-12BS DV	282,24	1411,2	199.5	997,5	230,58	1152,9
6	R110-DV turbo	351,54	1757,7	228.48	1142,4	288,96	1444,8

Tabela 5. Ušteda energije svetlosnih uređaja kod raznih modela traktora
Table 5. Energy saving lighting fixtures in a variety of models of tractors

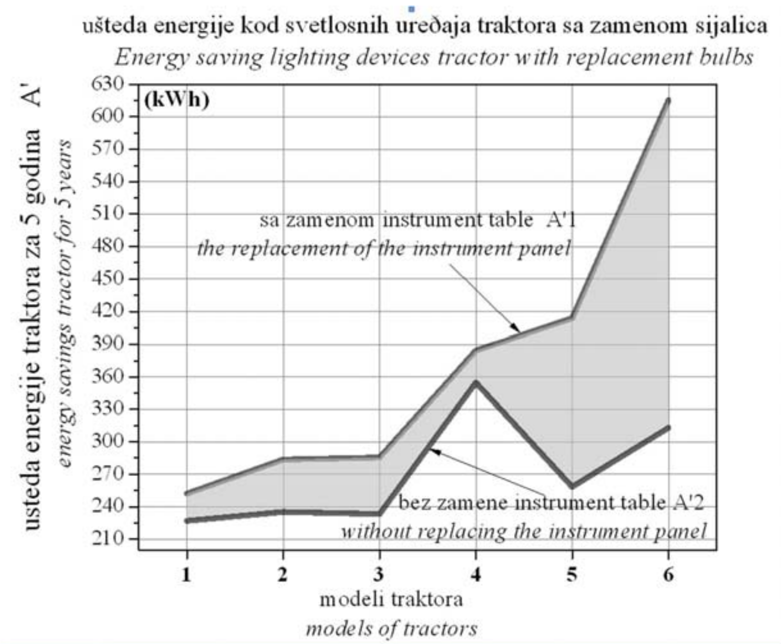
Ušteda energije u toku rada za 5godina *Energy savings during operation for 5 years* *A'* (kWh)			
Modeli traktora Models of tractors		Sa instrument tablom *From the dashboard* $A'1 = (A_{sta} - A_{sr1})$	Bez instrument table *No dashboard* $A'2 = (A_{sta} - A_{sr2})$
1	R47	252,0	226,8
2	R50 DV	283,5	235,2
3	R 60 transporter	285,6	233,1
4	R65	384,3	354,9
5	R65-12BS DV	413,7	258,3
6	R110-DV turbo	615.3	312.9

U Tab. 5. prikazana je ušteda energije traktora, za vremenski period od pet godina, ostvarena upotrebom i zamenom standardnih sijalica svetlosnih uređaja sa halogenim sijlaicama i LED modulima. Sa oznakom A′1(kWh) obeležena je ušteda energije sa potpunom zamenom svih standardnih sijalica svetlosnih uređaja traktora, a sa oznakom

A′2 (kWh) obeležena je ušteda energije sa delimično izvršenom zamenom standardnih sijalica, koja izuzima zamenu sijalica na instrument table traktora.

Prema podacima u Tab. 5. može se konstatovati da model traktora R110-DV turbo, kada se izvrši potpuna zamena standardnih sijalica sa halogenim i LED modulima, ostvari najveću uštedu energije za projektovani vremenski period od pet godina.

Na osnovu Tab. 5. dat je Graf. 1. radi transparentnog prikaza uštede energije, za sve model traktora, koju je moguće ostvariti zamenom standardnih sijalica svetlosnih uređaja traktora sa odgovarajućim halogenim sijalicama i LED modulima.



Grafik 1. Ušteda energije poljoprivrednih traktora pri upotrebi raznih sijalica
Chart 1. Energy saving agricultural tractors in use of different light bulbs

Posmatrajući projektovane podatke o uštedi energije ostvarene zamenom sijalica svetlosnih uređaja traktora kao i zvanične podatke sa popisa poljoprivrednih gazdinstava sprovedenog u Srbiji 2012. godine, može se sagledati značaj uštede energije. Upotrebljavajući sve navedene podatke iz Tab. 1. do Tab. 5., sačinjena je Tab. 6. gde je data prosečna ušteda energije obeležena sa A'pr (kWh) po formuli (3) kod modela traktora proizvođača IMR-a.

$$A'pr = \frac{\sum_{n=1}^{6} A'_n 1 + \sum_{n=1}^{6} A'_n 2}{2} \tag{3}$$

Ušteda energije je od značaja i za akumulator, kao osnovnog dela električnog sistema. Njegova osnovna funkcija je da obezbeđuje električnu energiju elektropoktrtaču i sistemu za paljenje koji pokreće traktor [8].

Tabela 6. Ušteda energije kod registrovanih traktora
Table 6. Energy saving of registered tractors

Prosečna ušteda energije kod modela traktora proizvođača IMR-a *The average energy savings in models of tractor manufacturers IMR*	A'_{pr} (kWh)	321,300
Broj registrovanih traktora u Srbiji *The number of registered tractors in Serbia*	(kom) *(pcs)*	410.894
Broj registrovanih traktora proizvođača IMR-a *The number of registered tractors manufacturers IMR*	(kom) *(pcs)*	246.536

Akumulator sadrži u sebi hemikalije i metalne ploče koje međusobno reaguju i po potrebi proizvode struju. Što je vreme hladnije odnosno niža spoljnja temperatura ili što je akumulator manje napunjen to je njegov rad slabiji [9]. Tako potpuno napunjen akumulator na T=25 (°C) proizvodi samo 65% potrebne energije a na T=0 (°C) i T= -15(°C) oko 40 %. U vremenskim uslovima sa sniženom temepraturom, kada je akumulator najslabiji tada je i najviše opterećen zbog potrebe da pokrene hladan motor. Na osnovu predhodno rečenog, ušteda energije ostvarena zamenom sijalica kod svetlosnih uređeja traktora je valjan doprinos. Uštedom energije broj paljenja motora se povećava oko 12%, u odnosu na deklarisani broj za novi akumulator, koji u proseku iznosi oko 4000 paljenja. Smanjena potrošnja energije kod poljoprivrednog traktora produžava vek akumulatora, što je od značaja u vremenskim uslovima sa sniženom temperaturom kao i sa ekološkog aspekta.

ZAKLJUČAK

Analizom potrošnje energije standardnih sijalica svetlosnih uređeja traktora i uštedom energije, ostvarenom sa sprovedenom odgovarajućom zamenom standardnih sijalica sa halogenim sijalicama i LED modulima na raznim modelima poljoprivrednih traktora proizvođača IMR-a, mogu se doneti sledeći zaključci:

- Halogene sijalice i LED moduli odaju veću količinu svetlosti, manju blještavost kao i veću svetlosnu efikasnost, pri manjoj deklarisnoj snagi u odnosu na standardne obične sijalice, što rukovaocu traktora daje komfornost i sigurnost u radu i saobraćaju.
- Upotrebom LED modula ostvaruje se ekološko unapređenje jer nisu toksični, ne zagađuju prirodu, traju duže od standardnih sijalica, nisu osetljivi na niske temperature a pri minimalnom naponu akumulatora odaju maksimalan sjaj.
- Dobijena ušteda energije kod poljoprivrednih traktora, ostavrena zamenom standardnih sijalica sa halogenim sijalicama i LED modulima, omogućava duži vek akumulatora, što je od značaja za rukovaoca traktora kao i sa ekološkog aspekta.

LITERATURA

[1] Knežević, R. 2003. Standard ii tehnička regulative u oblasti poljoprivredne mehanizacije – prikaz stanja i struktura organizacija. *Traktori i pogonske mašine.* 8:3 (189-195). Novi Sad

[2] Bracanović, Z., Borak, Đ., Grozdanić, B., Petrović, V. 2012. Luminous efficiency of argicultural tractors, MVM2012-008, *International Congress Motor Vehicles & Motors*, Kragujevac, Srbija, October 3rd-5th, 538 –542.

[3] Narendran, N., Hosseinzadeh, R. 2004. Estimating junction temperature of high-flux rwhite LEDs in Ligting emiting diods. *Research,mafacturing and applications VIII. Proceedings of SPIE* 5366.Prague,Czech Republic. http://www.odbornecasopisy.cz/res/pdf/39810.pdf (datum pristupa:12.03.2014.)

[4] Satoshi, K., Kenji, W., Masataka, H., Hisao, K.. 2011. *Ultraviolet Emission from a Diamond pn Junction*, Vol.292 no. 5523 pp. 1899-1901 DOI: 10.1126/science.1060258 Japan. http://www.sciencemag.org/content/292/5523/1899 (datum pristupa:13.02.2014)

[5] Ercegović, Đ., Raičević, D., Vukić, Đ. 2000. Faktori koji utiču na rad rukovaoca poljoprivrednih traktora. *Traktori i pogonske mašine* 5 (3-4). Novi Sad.

[6] Bracanović, Z., Grozdanić, Z., Toplak, Ž., Radosavljević, Z. 2000-2012. *Izveštaji sa laboratorijskih ispitivanja Instituta IMR*-a. Beograd.

[7] Bracanović, Z., Grozdanić, Z., Toplak, Ž., Radosavljević, Z. 2000-2012. *Izveštaji sa eksploatacionih ispitivanja Instituta* IMR-a. Beograd.

[8] Tomić, M. 2005. *Oprema motora*. Beograd: Mašinski fakultet.

[9] Schön, H. 2003. *Elektronik und Computer in der Landwirtschaft*. Eugen Ulmer GmbH; Stuttgart.

ENERGY SAVING OF AGRICULTURAL TRACTORS WHEN USING DIFFERENT TYPES OF BULBS

Zlata Bracanović[1], Velimir Petrović[1], Branka Grozdanić[1], Slobodan Janković[2]

[1] IMR Institute, Belgrade, Serbia,
[2] Technical Faculty of Mihajlo Pupin, Zrenjanin, Serbia.

Abstract: Advanced technologies contributed to the modernization of the tractor, enable the tractor operator efficiency, comfort, safety at work and the movement of traffic. Halogen bulbs and LED modules, as components for updating lighting fixtures of tractors, give a greater amount of light without shadows and brightness. LED modules is characterized by low nominal power and heat broadcasting, due to its composition are non-toxic.

Looking characteristics and purpose of standard bulbs, which are used in agricultural tractor unit of light, is given adequate substitute them with halogen lamps and LED modules. We analyzed the minimum and maximum energy consumption for six models of agricultural tractors production of IMR, when using different light bulbs. There are given some possible variations in the observed energy saving models of tractors, achieved by replacing standard light bulbs to light devices and dashboard of the tractor.

According to the official data on the number of agricultural tractors related to the agricultural census, in Serbia there are around 410 894 double-axle tractors. If it is assumed that 60% of registered tractors production of IMR, I came across fact on possible energy savings for a designed period of time.

Key words: *tractor, LED modules, energy.*

Prijavljen:
Submitted: 25.5.2014
Ispravljen:
Revised:
Prihvaćen:
Accepted: 07.09.2014

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 85 – 97

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 85 – 97

UDK: 517.925

Originalni naučni rad
Original scientific paper

STOCHASTIC GENERATOR FOR A REAL-TIME WIND SIMULATION

Zuzana Palková*, Lukáš Tomášik

Slovak University of Agriculture in Nitra, Faculty of Engineering,
Department of Electrical Engineering, Automation and Informatics
Nitra, Slovakia

Abstract: In nature, wind is considered to be a stochastic attribute of weather, whose momentary speed and direction are easily measureable, but extremely hard or nearly impossible to predict. Wind simulation is used in many fields of computer processing and modeling. Our stochastic generator is primary designed for use in wind modeling in the simulations of irrigation processes. In real world there is an event, rather a movement that is generally considered to be unable to predict – a flight of a real object. In real conditions, every object thrown in any direction, other than straight down, moves along a ballistic curve. Our method is based on simulating the flight of high number of objects and collisions between them. Collisions are implemented for two main reasons – to move objects in a bounded finite space when collisions with borders are implemented, and to change the objects' directions at a time of a collision to make objects to stay in space.

Key words: *ball collision, stochastic generator, true-random generator, wind simulation*

INTRODUCTION

In nature, wind is considered to be a stochastic attribute of weather, whose momentary speed and direction are easily measureable, but extremely hard or nearly impossible to predict. With simplification, we can predict that values of the wind speed and direction will fall in a specific interval. Wind simulation is used in many fields of

* Corresponding author. E-mail: zuzana.palkova@uniag.sk

computer processing and modeling, including physical simulation, demos and of course, in some current games.

For simulating the stochastic attributes of wind in computer modeling, random numbers generators and generators based on deterministic chaos are used at most. Prediction of wind speed and direction, like most meteorological variables, is extremely difficult. Even with advanced technology, such as sophisticated numerical models and super computers, using climatological means is as accurate as predicting meteorological variables for a time period of more than a few days in advance (Tribbia, *et al*., 1987)

Our stochastic generator is primary designed for use in wind modeling in the simulations of irrigation processes. In these kinds of simulations, we need a real-time generator to simulate the actual wind speed and direction in a very small time delays – for example tens of seconds.

Sometimes knowing wind speed without concern for wind direction is sufficient and, thus, many of the wind studies do not consider a wind direction component (Skidmore, 1987). Generators based on statistic data of wind speed and direction per day or month are good for obtaining the maximum, minimum and average values of wind speed, as well as its direction, but are unsuitable for real-time simulation because of the absence of accurate data in the actual time step. These missing data cannot be calculated using interpolation or approximation because this would result in a quite flat real-time data.

General pseudo-random generators that are primary used in the fields of computer modeling, where sharp peeks in the output random data wave are allowed, or there is high need of speed. These pseudo-random generators are based, with small differences, on the following equation (Claus, *et al*., 1986):

$$z = (a * z + c) \bmod p \tag{1}$$

Where a, c and p are integer or float constants and z is called a "Seed". This is the initial pseudo-random value, usually calculated out of the machine system time from milliseconds or sometimes microseconds. When the new value Rand is generated, it replaces the one of the constant from the Equation 1. The data flow generated from this kind of generators can looks like Fig.1.

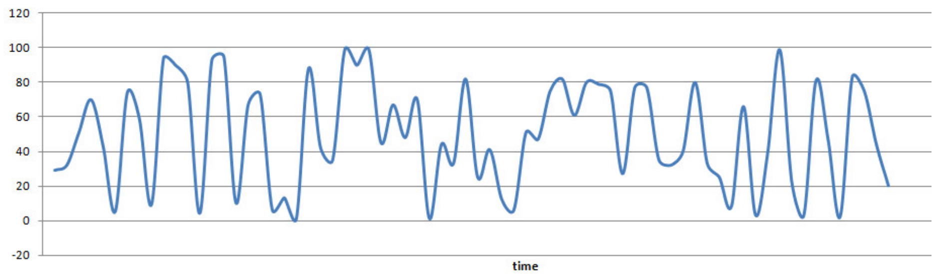


Figure 1. Data flow from a typical pseudo-random generator

As shown on Fig. 1, the output wave contains many sharp peaks. According to the principles of pseudo-random generators, the change of randomness of the data is very good, but the format of output wave is unsuitable for real-time wind modeling. This data will cause the wind model to very quickly increase and decrease its speed, or a direction, the event that is not natural.

The main subject of this article is to present a new method of stochastic generator for use in the computer wind simulation based on clear natural principles. In nature, many events occur, that are considered to be stochastic and it is hard to simulate them on computers. These events are appropriate for true-random generators, where the character of the data wave is truly unpredictable and nondeterministic. After simulating these events on a computer, we cannot fully preserve the true-random factor, but we can approximate this behavior as much as possible.

MATERIAL AND METHODS

Our intention was to design a stochastic generator based on a clear natural principles. Even the designed generator is executed on a computer, its output random values are independent on computer local system time, unlike other general random functions. Its output values are nearly the same as would be measured when simulating the generator's job in real world with real conditions. In the previous sentence, the word "nearly" was used – we omitted some attributes and events that normally occur in nature, but for our purpose they are unnecessary.

In real world there is an event, rather a movement that is generally considered to be unable to predict – a flight of a real object. In real conditions, every object thrown in any direction, other than straight down, moves along a ballistic curve. Generally, actual position of a flying object has to be simulated from its starting position to actual position at a specific time. The reason is that this movement cannot be directly calculated, because of quite large number or factors that influence the movement of an object, including drag force, gravity, and the Corioli's force. The drag force depends at most on object's speed – higher the object's speed, the higher the drag force and vice versa – this is probably the most important factor, why the flight along the ballistic curve is not predictable – the drag force slows down the object, simultaneously the drag force is lowered by slowing of an object.

Simulating the flight of one object was inadequate for our intention – there are no random values of a specific pre-defined interval that can be extracted out of the simulation, we would be able to extract only a position of an object at a time. Our method is based on simulating the flight of high number of objects and collisions between them. The collision is implemented for two main reasons – to move objects in a bounded finite space when collisions with borders are implemented, and to change the objects' directions at a time of a collision. As objects, we have chosen to work with balls as there is no need to consider objects' rotations.

Our method of stochastic generator has been divided into three basic steps – first step is to simulate totally elastic 2D collision of balls of finite mass including Newton's conservation of momentum. In the second step, the drag force of the fluid is included in the computation. The drag force causes the movement of the ball to be harder to predict, because this force slows down the ball in both directions and is directly proportional to the square of the object's speed. There are some other factors that influence the value of this force, like density of the fluid where the object moves and the shape of the object.

With possible application of gravity, the ball would move along the ballistic curve. There is no equation to directly compute the trajectory of ballistic curve, existing programs simulate the flight of object – for example a projectile – to get the hit point. This means that the spot, where the ball hits the ground is not able to be determined in one-step computation. In our method, we omitted the gravity, because it has a minor change in the stochastic factor of the whole generator. In the last third step, we calculate the area of the triangles drawn by every triplet of balls. The higher number of triplets, the smoother the generator.

Step 1: Elastic 2D collision

We considered two balls named b_1 and b_2 with finite masses m_1, m_2 and velocities v_1 and v_2. The Fig. 2 illustrates the typical collision of these two balls. The two balls collide, when the distance between their centers is equal to the sum of their radiuses. In computer modeling based on discrete time frames, we allow this distance to be less in just one frame, to just properly detect collision.

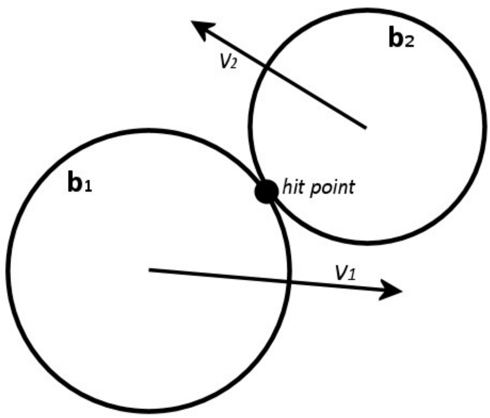


Figure 2. General situation of ball collision in 2D

According to the Fig. 2, we mark the spot, where two balls collide the "hit point". There are actually three phases of ball collision – the first phase takes place one frame before the collision, the second phase is the frame when the balls collide and the balls "exchange" their velocity vectors according to the conservation of momentum and conservation of kinetic energy. Finally, the last third phase is the frame where the balls moves in changed directions – the frame right after the collision. The situation illustrated on Fig. 2 is a combination of the first and the second phase.

After getting the actual hit point, we find the axis of collision. The axis of collision is the axis that passes through the centers of the balls and the actual hit point. Then we break up the velocity vectors v_1, v_2 into their components v_{x1}, v_{y1}, v_{x2}, v_{y2} in two-dimensional space, as shown on the Fig. 3.

Finding the axis of collision is a very important operation, because all the change in velocities of both balls occurs only in component vectors v_{x1} and v_{x2} – the vectors parallel to the axis of collision. The component vectors v_{y1} and v_{y2} remain unchanged.

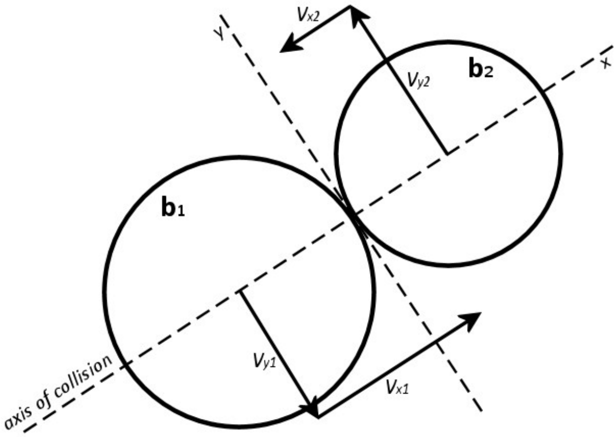


Figure 3. Breaking the velocity vectors into their components according to the axis of collision

When the balls in a collision are of the same mass, we can just exchange their velocity vectors v_{x1} and v_{x2} and make them opposite by multiplying them by a scalar-*1*. The situation after this operation is illustrated on the Fig. 4.

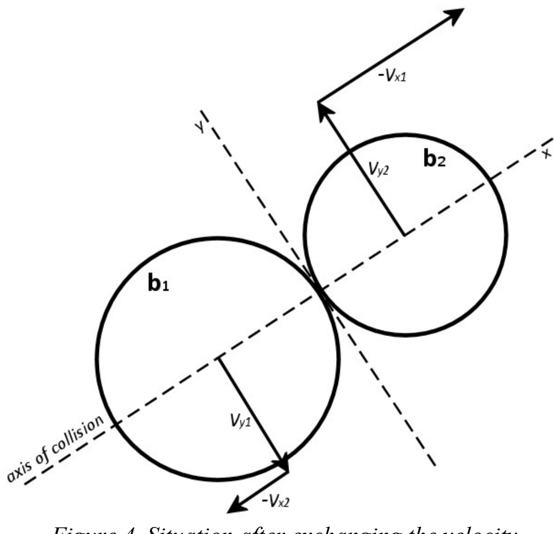


Figure 4. Situation after exchanging the velocity component vectors

The sum of the new component vectors gives the new velocity vectors v_{n1}, v_{n2}. After the collision, the balls move according to these vectors.

When the two balls are not of the same mass, the exchange of the velocity component vectors is not enough and their values must be calculated using following formulas:

$$v_{final1} = \frac{v_1(m_1 - m_2) + 2m_2v_2}{m_1 + m_2} v_{final2} = \frac{v_2(m_2 - m_1) + 2m_1v_1}{m_1 + m_2} \quad (2)$$

Our random generator works with balls of different (random) masses, the calculation of velocities is made using the Eq. 2 with a little change. As we work in a 2D space, all vectors have two coordinates *X* and *Y*. Even, there is a vector of acceleration for each ball, the calculation is applied for velocity vectors only.

The procedure of finding the final velocities after the collision starts with finding the unit vector *u* from the two balls' coordinates.

$$u = [\mathrm{p_{1x}} - \mathrm{p_{2x}}\,;\ \mathrm{p_{1y}} - \mathrm{p_{2y}}] \quad (3)$$

In the above equation, p_{1x} and p_{1y} represent the position of first ball. Similarly, p_{2x} and p_{2y} represent the position of second ball. Both these positions are taken right at a time of a collision. It principally does not matter which ball is marked *1* or *2*.

Before breaking the ball's velocity vector into component vectors, we calculated the unit vector *n*, marked as *un*:

$$un = \left[\frac{n.X}{\sqrt{n.X^2 + n.Y^2}}\,;\ \frac{n.Y}{\sqrt{n.X^2 + n.Y^2}}\right] \quad (4)$$

To break velocity vector into its component vectors we calculated the dot product of ball's velocity vector and the unit vector *un*. The equation we used looks like as follows:

$$\left|v_{x1(2)}\right| = v_{1(2)}.X \cdot un.X + v_{1(2)}.Y \cdot un.Y \quad (5)$$

Components vectors v_{x1} and v_{x2} are parallel to the axis of collision, but to calculate the final velocity vectors of each ball out of this component vectors, we must preserve the component vectors that are preserve to the axis of collision – vectors v_{y1} and v_{y2}. The equations similar to the previous one, but instead of vector *un*, we used the normal vector of *un*.

$$\left|v_{y1(2)}\right| = v_{1(2)}.X \cdot un.Y + v_{1(2)}.Y \cdot (-un).X \quad (6)$$

The next step is to calculate new size of velocity components vectors v_{x1} and v_{x2} using the general Eq. 2. Vectors v_{y1} and v_{y2} remain unchanged.

To calculate the final velocities right after the collision is simple - the sum of the components vectors gets us the final vector of velocity.

Step 2: The drag force

Drag force is a force that counteracts the movement of any real object in real fluids. In the non-inertia systems that we are simulating, it results in a negative acceleration against the movement of the ball.

The drag force translated into 2D space is calculated using the following equation:

$$F_d = \left[\frac{1}{2}\,\varrho\,C_d\,v.X^2\,A\,;\,\frac{1}{2}\,\varrho\,C_d\,v.Y^2\,A\right] \quad (7)$$

Where:

F_d density of the fluid,

C_d drag coefficient, for a sphere the value is *0.47,*

A area of an object perpendicular to the direction of movement, in our case calculated as πr^2.

According to the Newton's second law of movement, the negative acceleration to the ball's movement is calculated this way:

$$a = \left[-\frac{F_d.X}{m}\,;-\frac{F_d.Y}{m}\right] \quad (8)$$

Where:

m weight (mass) of the ball.

Step 3: Creating triangles out of ball triplets

With every ball triplet, our generator creates a triangle, which vertexes are equal to the balls' centers. The perimeters and areas of these triangles are very stochastic and almost impossible to predict. The generator could use only calculation of perimeters, but we decided to calculate the area of triangles to generate more peaks in a random data wave. After the area of the triangle is known, we compare it to the maximum possible area of triangle – when using square space, like in our case, the maximum possible area of triangle is the half of the area of space where the balls move.

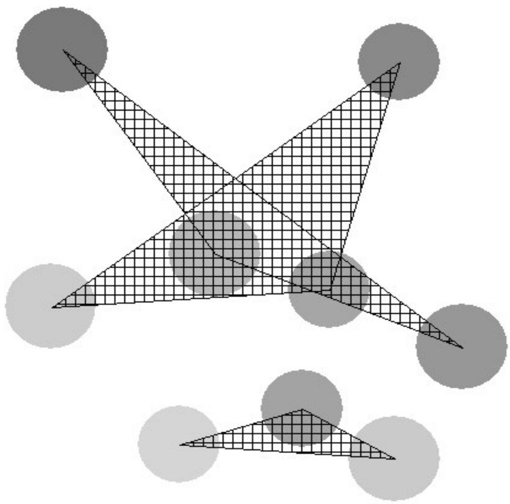


Figure 5. Creating triangles out of ball triplets

On Fig. 5, a screenshot of our generator is shown. The total size of cross-filled area is compared to the maximum possible area of triangle multiplied by the number of triplets. On the picture above, there are three ball triplets. The higher number of triplets, the smoother the generator is.

RESULTS AND DISCUSSION

Using our generator, we simulated the flight and collisions of balls in three liquids, which vary in density:

- air,
- water,
- mercury.

Table 1. Stochastic data flow in air– ϱ=1.220 kg.m^3, 3 triplets

Time step	Data	Time step	Data	Time step	Data	Time step	Data	Time step	Data
1	12,58	26	8,62	51	39,48	76	37,39	101	12,77
2	22,56	27	14,31	52	41,79	77	40,97	102	20,82
3	35,23	28	23,56	53	37,74	78	47,17	103	23,66
4	40,32	29	32,19	54	39,53	79	43,48	104	34,27
5	38,68	30	25,51	55	38,19	80	28,27	105	42,58
6	25,82	31	16,75	56	37,41	81	21,91	106	31,44
7	26,07	32	23,81	57	49,00	82	40,78	107	19,25
8	17,34	33	22,92	58	47,88	83	53,91	108	11,26
9	6,83	34	14,15	59	34,41	84	38,15	109	9,08
10	8,70	35	8,83	60	27,16	85	29,86	110	10,72
11	13,13	36	13,84	61	32,27	86	27,61	111	10,53
12	10,59	37	15,19	62	50,12	87	22,48	112	19,30
13	16,12	38	20,16	63	44,49	88	19,11	113	21,97
14	14,62	39	29,63	64	31,30	89	26,56	114	14,70
15	15,52	40	25,80	65	34,44	90	20,50	115	12,84
16	26,98	41	29,83	66	29,97	91	15,42	116	27,95
17	31,65	42	22,28	67	28,84	92	18,28	117	39,10
18	36,15	43	16,11	68	34,05	93	19,11	118	39,43
19	29,33	44	24,11	69	33,46	94	25,91	119	39,16
20	29,37	45	24,21	70	34,93	95	31,12	120	37,11
21	33,63	46	25,89	71	35,09	96	34,96	121	37,07
22	32,57	47	29,15	72	36,44	97	29,91	122	33,64
23	21,26	48	30,64	73	43,47	98	26,77	123	30,05
24	10,57	49	23,14	74	53,03	99	19,02	124	26,03
25	6,18	50	21,74	75	51,53	100	11,94	125	31,20

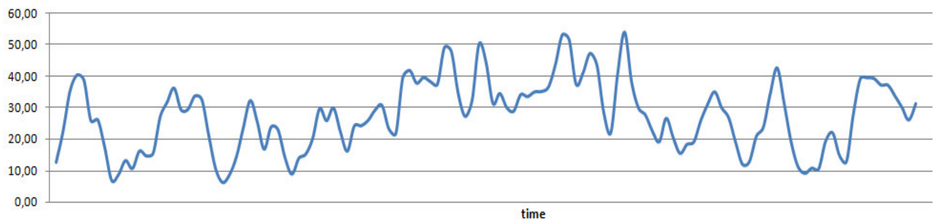


Figure 6. Stochastic data flow in air

Table 2. Stochastic data flow in water–ϱ=1000 kg.m^3, 3 triplets, 2 cycles

Time step	Data	Time step	Data	Time step	Data	Time step	Data	Time step	Data
1	16,49	26	14,36	51	25,84	76	41,32	101	13,72
2	21,00	27	20,51	52	26,14	77	40,01	102	12,40
3	24,33	28	15,76	53	33,09	78	37,96	103	13,90
4	25,58	29	23,01	54	32,59	79	32,58	104	19,06
5	38,02	30	33,08	55	31,63	80	38,56	105	22,34
6	48,82	31	39,37	56	26,15	81	45,58	106	23,02
7	42,25	32	38,91	57	23,74	82	37,92	107	35,92
8	27,43	33	42,45	58	26,32	83	25,93	108	41,68
9	26,41	34	48,34	59	31,87	84	23,85	109	38,62
10	33,03	35	41,74	60	32,96	85	30,40	110	33,72
11	39,21	36	28,92	61	25,59	86	38,05	111	26,92
12	41,78	37	28,95	62	33,36	87	35,40	112	21,78
13	42,44	38	32,19	63	41,13	88	32,34	113	20,10
14	46,45	39	25,57	64	33,10	89	31,78	114	22,95
15	34,18	40	24,32	65	27,39	90	45,76	115	19,92
16	20,66	41	32,91	66	19,56	91	54,70	116	16,70
17	10,96	42	32,26	67	20,88	92	63,38	117	20,54
18	19,56	43	21,51	68	26,99	93	47,42	118	20,65
19	28,63	44	14,48	69	24,90	94	45,12	119	19,35
20	27,08	45	7,01	70	25,95	95	55,69	120	18,02
21	26,39	46	11,17	71	31,29	96	54,99	121	20,45
22	25,16	47	15,91	72	33,40	97	48,60	122	21,90
23	20,72	48	13,45	73	36,43	98	31,64	123	20,93
24	8,64	49	16,46	74	39,91	99	21,33	124	24,63
25	13,66	50	20,85	75	40,96	100	19,64	125	20,14

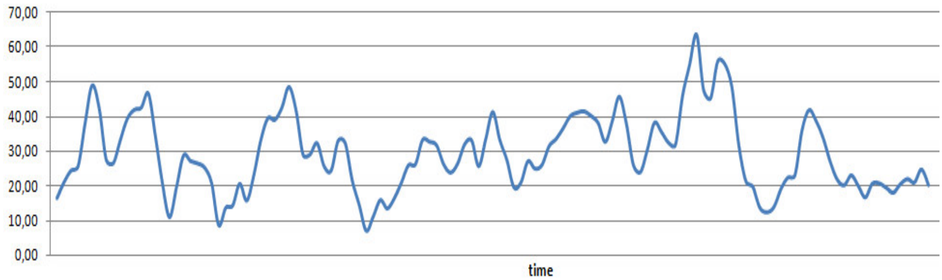


Figure 7. Stochastic data flow in water

Table 3. Stochastic data flow in mercury–ϱ=13534 kg.m^3, 3 triplets, 2 cycles

Time step	Data	Time step	Data	Time step	Data	Time step	Data	Time step	Data
1	5,95	26	36,53	51	38,38	76	22,57	101	46,41
2	7,09	27	28,47	52	33,95	77	29,09	102	55,27
3	7,27	28	29,22	53	30,25	78	28,72	103	49,37
4	14,23	29	31,54	54	34,65	79	23,40	104	45,18
5	20,52	30	38,45	55	34,83	80	13,98	105	48,59
6	19,36	31	37,57	56	32,66	81	11,78	106	52,89

Time step	*Data*	*Time step*	*Data*	*Time step*	*Data*	*Time step*	*Data*	*Time step*	*Data*
7	*12,69*	*32*	*36,73*	*57*	*36,26*	*82*	*9,55*	*107*	*54,67*
8	*10,25*	*33*	*34,64*	*58*	*33,92*	*83*	*13,52*	*108*	*52,58*
9	*24,07*	*34*	*34,05*	*59*	*31,28*	*84*	*18,64*	*109*	*48,35*
10	*22,91*	*35*	*29,23*	*60*	*32,08*	*85*	*20,91*	*110*	*45,69*
11	*24,63*	*36*	*36,69*	*61*	*32,36*	*86*	*21,70*	*111*	*46,95*
12	*25,46*	*37*	*37,61*	*62*	*26,39*	*87*	*25,81*	*112*	*44,26*
13	*34,53*	*38*	*32,22*	*63*	*24,49*	*88*	*22,51*	*113*	*39,34*
14	*42,52*	*39*	*30,77*	*64*	*22,37*	*89*	*15,86*	*114*	*38,04*
15	*40,71*	*40*	*33,34*	*65*	*19,28*	*90*	*9,08*	*115*	*40,36*
16	*39,34*	*41*	*30,37*	*66*	*18,87*	*91*	*14,85*	*116*	*42,43*
17	*38,48*	*42*	*26,26*	*67*	*20,34*	*92*	*23,09*	*117*	*44,06*
18	*31,24*	*43*	*23,06*	*68*	*25,13*	*93*	*25,39*	*118*	*44,36*
19	*19,70*	*44*	*28,67*	*69*	*26,82*	*94*	*24,01*	*119*	*44,91*
20	*14,90*	*45*	*34,88*	*70*	*24,49*	*95*	*30,87*	*120*	*45,35*
21	*12,79*	*46*	*36,24*	*71*	*22,06*	*96*	*36,83*	*121*	*44,12*
22	*19,69*	*47*	*46,06*	*72*	*19,68*	*97*	*33,73*	*122*	*43,35*
23	*29,60*	*48*	*57,17*	*73*	*12,00*	*98*	*31,30*	*123*	*50,47*
24	*38,24*	*49*	*51,65*	*74*	*11,82*	*99*	*33,12*	*124*	*49,68*
25	*40,45*	*50*	*45,82*	*75*	*20,02*	*100*	*39,62*	*125*	*47,79*

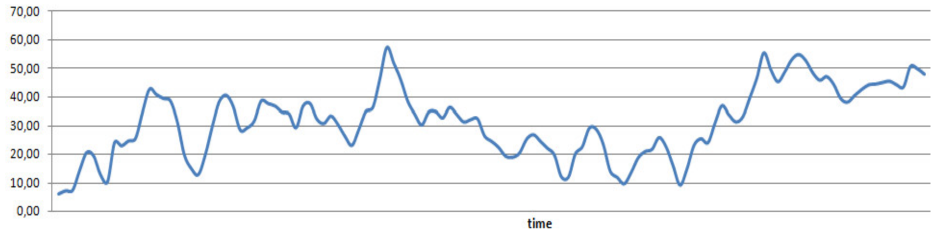


Figure 8. Stochastic data flow in mercury

As diagrams above show, with increasing the density of the fluid, the generator produces smoother waves. In all cases, the waves have very stochastic, non-periodic behavior.

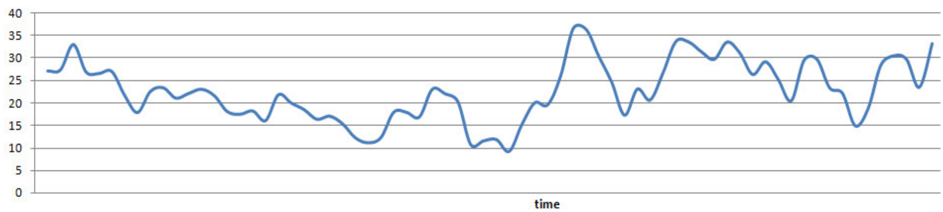


Figure 9. Stochastic data flow in water – 6 triplets

The waves are just an array of float numbers representing the current random value in a particular time. With these values we can simulate both speed and direction of wind, even with different parameters.

The system of our stochastic generator is very open to an ability of influencing its behavior by changing a high number of attributes like balls' initial velocities or accelerations, masses, radiuses, fluid density and even the generator uses only balls, by changing the C_d *(Eq. 7)* value, we can simulate aerodynamic behavior of any other shapes. There is also a very high ability to change the smoothness and variability of the output data by changing the number of ball triplets. For comparison, we generated two data flows – one with 6 triplets and second with 12 triplets, both in water.

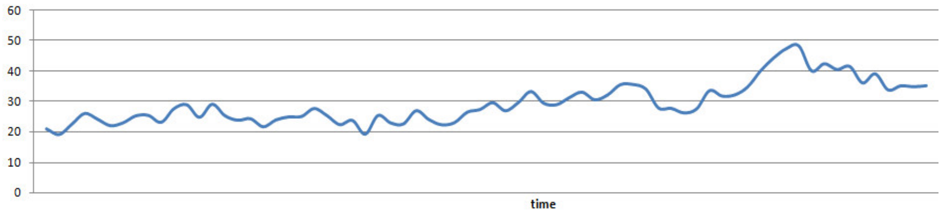


Figure 10. Stochastic data flow in water – 12 triplets

As Figs. 9 and 10 present, by increasing the number of ball triplets, we can simply increase the smoothness of the output data. The data wave becomes flatter.

CONCLUSIONS

Designed stochastic generator simulates true-random events in nature – flight of objects in a specific fluid where the drag force slows down any object, in other words simulates the unpredictable flight along a ballistic curve. To make the generator run for almost infinite time, we applied collisions of objects and omit gravity. The generator produces output random data flow that can be used in any application as its input data.

The character of data flow is non-periodic and nondeterministic. It does not contain sharp peaks and is smooth as the computer wind model has to be.

Main advantages of our stochastic generator are listed:

- based on a clear natural principle, which is considered to be stochastic or true-random,
- very high ability to produce stochastic and non-periodic waves,
- ability to easily set the smoothness of the generator – by increasing the density of fluid or by increasing the number of balls triplets,
- can run for a practically infinite time,
- easily to be implement in all fields of computer simulations of stochastic features.

To present the generator's primary goal – to simulate effects of wind in the irrigation process, we have created a time-based irrigation model that simulates the irrigation with a standard pivot sprinkler. With optimal weather conditions (no wind), the irrigated area is of an exactly circular. After adding a response to our generator, we change the trajectory of water drops according to the blowing wind. The direction of wind was set to NW and its velocity was generated during a period of time.

The results are shown on the Fig. 11.

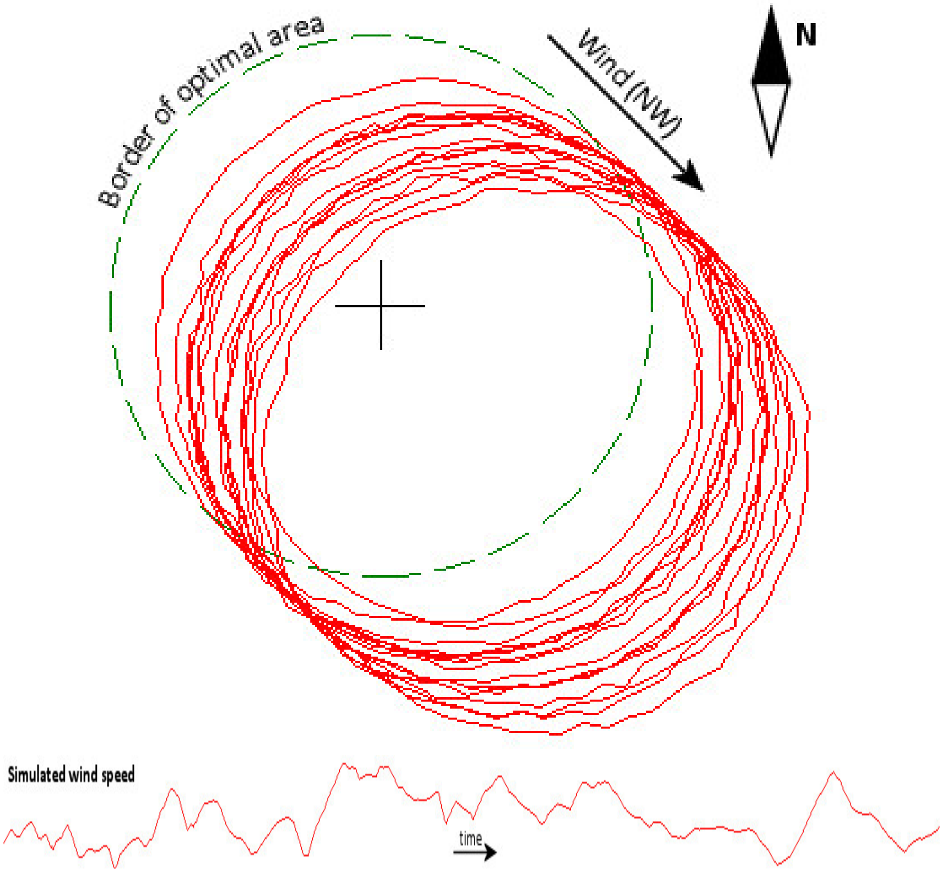


Figure 11. Results of the wind modeling using a pivot sprinkler

On Fig. 11, the sprinkler was placed at the cross mark, right in the middle of the circular irrigated area. According to the effect of wind, the shape of this area is changed as the trajectories of water drops are influenced by the wind speed and its direction.
Using of our designed generator helps to improve the agricultural production, as we can simulate the efficiency of irrigation during almost any weather conditions.

BIBLIOGRAPHY

[1] Claus, V., Schwill, A., 1986. *Schülerduden – Die Informatik*. Mannheim: Bibliographisches Institut 1986, ISBN 3-411-02213-2

[2] Capinski M., Zastawniak T. J., 2001. *Probability Through Problems*. Springer 2001, ISBN 978-0-387-95063-1

[3] Newton, R. G., 2002. *Thinking About Physics*. 2002. Princeton University Press 2002. ISBN 9780691095530

[4] Allen, M.P., Tildesley, D.J., 2002. *Computer Simulation of Liquids*. 1989. Clarendon Press 2002. ISBN 9-7801-9855645-9

[5] Stirzaker, D., 2005. *Stochastic Processes and Models*. 2005. Oxford University Press. ISBN 0-198-56814-2

[6] Gardiner, C.W., 2011. *Stochastic Methods.* 2011. Springer-Verlag Berlin and Heidelberg GmbH & Co. K. 2011. ISBN 3-540-70712-3

[7] Abarbanel, H.D.I., 1996. *Analysis of Observed Chaotic Data*. Springer-Verlag 1996.

[8] Tribbia, J.J., Anthes, R.A. 1987. Scientific basis of modern weather prediction. 1987. *Science* 237: 493-499

[9] Skidmore, E.L., 1987. Wind-erosion direction factors as influenced by field shape and wind preponderance. 1987. *Soil Sci. Soc. Am. J.* 51: 198-202

STOHASTIČKI GENERATOR ZA SIMULACIJU VETRA U REALNOM VREMENU

Zuzana Palková, Lukáš Tomášik

Slovački poljoprivredni univerzitet u Nitri, Tehnički fakultet, Institut za elektrotehniku, automatiku i informatiku, Nitra, Slovačka

Sažetak: U prirodi se vetar smatra stohastičkim atributom vremena, čiji se trenutni brzina i smer mogu lako izmeriti, ali ih je veoma teško ili gotovo nemoguće predvideti. Simulacija vetra se koristi u mnogim oblastima računarske obrade i modeliranja. Naš stohastički generator je primarno konstruisan za upotrebu u modeliranju vetra u simulacijama postupaka navodnjavanja. U stvarnom svetu postoji jedan događaj, ili bolje pokret koji smatra da je nemoguće predviđanje leta realnog objekta. U stvarnim uslovima, svaki predmet bačen u bilo kom smeru, izuzev pravo dole, kreće se po balističkoj krivoj. Naš metod se zasniva na simulaciji leta velikog broja objekata i njihovih međusobnih sudara. Sudari su uvršteni iz dva glavna razloga – da pomeraju objekte u ograničenom konačnom prostoru kada su uvršteni sudari sa granicama, i da menjaju smerove objekata u vreme sudara da bi objekti ostali u prostoru.

Ključne reči: *sudar lopte, stohastički generator, stvarni-nasumični generator, simulacija vetra*

Prijavljen: *Submitted*: 07.02.2014
Ispravljen: *Revised*:
Prihvaćen: *Accepted*: 07.09.2014

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XXXIX
Broj 3, 2014.
Strane: 99 – 113

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XXXIX
No. 3, 2014.
pp: 99 – 113

UDK:631(059)

Originalni naučni rad
Original scientific paper

HEAT TRANSFER COEFFICIENT AND CONCEPT OF RELAXATION TIME IN FORCED AIR DIRECT EVAPORATIVE COOLING SYSTEM

Ndukwu M.Chinenye[1, 2*], Seth.I.Manuwa[2]

[1]*Michael Okpara University of Agriculture Umudike, Department of Agricultural and Bioresources Engineering, Umuahia, Abia State, Nigeria*
[2]*Federal University of Technology Akure, Department of Agricultural Engineering, Akure Ondo State, Nigeria*

Abstract: Evaporative cooling system with palm fruit fiber as cooling pad was studied at different ambient air temperature and relative humidity. Experiment was conducted with a prototyped direct evaporative cooling system for preservation of fruits and vegetable of moderate respiratory rates at a low flow rate of 0.6 $m^3 \cdot s^{-1}$. Three different models were proposed and used to obtain the heat transfer coefficient at different evaporative effectiveness. For the three models, the heat transfer coefficient varied from 173 to 857 $W \cdot m^{-2} K^{-1}$. The relaxation time was predicted as a finite time process and the value calculated from the model can be regarded as a hypothetical value since other heat transfer methods like conduction or even radiation loss were neglected. Therefore the value calculated might be much higher than the real relaxation time. For ambient air temperature range of 26.1 to 34.8°C which was cooled to 23.2 to 25.8°C, the average relaxation time was calculated as 0.71 to 1.68 s.

Key words: *Ambient temperature, evaporative cooling, heat transfer, relative humidity*

INTRODUCTION

Evaporative cooling system is an environmentally friendly air-conditioning system that uses water as the working fluid [1] which can be adapted to cool residential houses,

[*] Corresponding author. Email: ndukwumcu@gmail.com.

production process in metallurgical shops, preserve fruits and vegetables, cool automobile engine and tractor cabins. When water evaporates it draws a considerable energy from its environment which produces considerable cooling effects. The wet porous media provides the environment for this to take place.

Basic principle involves the movement of air that is not too humid across this wet porous media causing evaporation of water from the pad media. This air movement results in two favorable changes, a reduction in ambient air temperature and increase in relative humidity of incoming air. Evaporative cooling is an adiabatic heat transfer process involving the process fluids (air and water). The sensible heat of air is reduced proportionally to the amount of evaporation that takes place [2].

The parameter for the energy balance equation across the wet porous pad includes the heat transfer coefficients and the temperature difference [3] [4]. These parameters are influenced by the type of pad material and the air speed [5]. [6] Stated that equipment design depends greatly upon reliable equations for explaining the heat transfer process in a system.

Therefore theoretical analysis on evaporative cooling is important for revealing the heat and mass transfer laws in evaporative cooling process as well as for predicting the process outputs under various operating and environmental conditions. Some equations have been developed to consider the heat and mass transfer in evaporative cooling [5][7][8][9]. All these models include the heat transfer coefficient and temperature difference of the process fluids. Also literature on how long the cooling process of the ambient air to storage space temperature takes under the tested conditions, which will give room for any modification, is very scarce.

The objectives of this study is to present information on the heat transfer coefficient using some model equations and guess the relaxation time in an evaporative cooling system. This will provide important knowledge for evaporative cooler design especially in rural area in Africa where local waste is used as a substitute for expensive and unavailable pad media.

MATERIAL AND METHODS

Cooling pad

Palm fruit fiber was used as the cooling pad. It was obtained from local palm oil processing industries which generates this material as a waste in there factory. The material was thoroughly washed with detergent, rinsed several times with water and allowed to dry under the sun for several days.

Evaporative cooling system

The evaporative cooling system used for the experiment was developed at the research workshop of the Agricultural Engineering Department of Federal University of Technology Akure. The evaporative cooler (Fig. 1) was developed for the storage of fruits and vegetables of moderate respiratory rate and has been presented in [10].

Experimental measurements

Experiment was conducted with small prototype evaporative cooling system (Fig. 1) for preservation of fruits and vegetables. The porous cooling pad was rigidly parked inside the pad holder at a pad thickness of 30 mm and a parking density of 20 – 22 kg·m^{-3}. Dry bulb temperature was measured with thermocouple (Omega HHI147) for the draft or ambient air (T_1), the cold chamber of the cooler (T_2), the supply water temperature (T_3) and the sump water temperature (T_4). Also the wet bulb temperature of the cold chamber was also recorded. The air flow rate was measured at five locations 3cm from each point measured longitudinally between the pad media and the axial fan with vane microprocessor (AM-4826) digital anemometer (±0.1 m·s^{-1}).

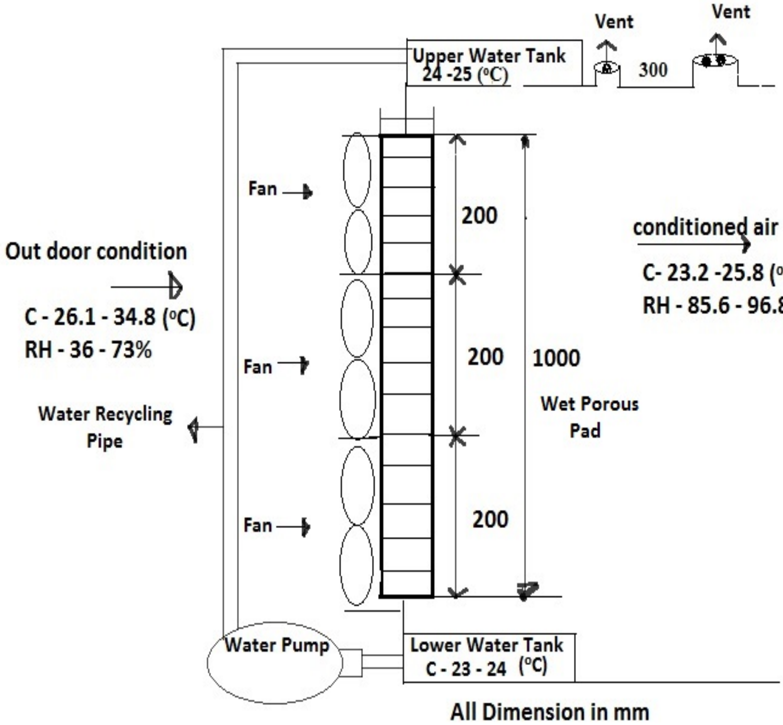


Figure 1. Schematic view of direct evaporative cooling system

The data was logged every two hours to record the temperatures. The cooling effectiveness (ε) was calculated from the equation presented by [11]. The relative humidity of draft air (Rh_1) was measured with humidity clock while that off the cold chamber (Rh_2) was calculated with psychometric calculator. The experiment was carried out from the month of January to June when the relative humidity is relatively low and evaporative cooling possible in southern part of Nigeria. Though by June, rain is becoming frequent and evaporative cooling less efficient. However for the sake of this paper and for easy assimilation, typical three consecutive day's data for January were presented and used in the model evaluation.

The evaluation parameters are as follows:

- Pad type: Oil palm fruit fiber
- Water holding capacity: 2.05 kg of water per kg of solid
- Bulk density: 47.8 $kg{\cdot}m^{-3}$
- Air speed: 4 $m{\cdot}s^{-1}$
- Air mass flow rate: 0.6 $m^3{\cdot}s^{-1}$
- Ambient air temperature range: 26.1- 34.8°C
- Cold air temperature range: 23.2 - 25.8°C
- Ambient air relative humidity: 36.0- 73.0%
- Cold air relative humidity: 85.6 - 96.8%
- Evaporative effectiveness: 70.0 - 98.8%

Heat transfer coefficient

A total of three heat transfer equation was used to model the heat transfer coefficient of the system. Statistical parameter such as R^2 was used to assess the goodness of fitting.

***Process modeling* (A)**

The energy balance applied to a small section of the pad media as a heat transfer surface can be written as:

$$dq = hA(T_w - T)dt = C_p \rho V dT \tag{1}$$

Where:

q $[W{\cdot}m^{-2}]$ - heat flux,
h $[W{\cdot}m^{-2}K^{-1}]$ - convective heat transfer coefficient of the outside air,
T_w [°C] - wet bulb temperature,
T [°C] - dry bulb temperature,
A $[m^2]$ - surface area of the pad,
T [s] - time,
C_p $[J{\cdot}kg^{-1}K^{-1}]$ - specific heat of air,
V $[m^3]$ - volume of the pad,
ρ $[kg{\cdot}m^{-3}]$ - density of air.

Integrating between the limits $T = T_0$ at $t = 0$ and $T = T$ when $t = t$ [6]:

$$q = \int_{T_0}^{T} \frac{dT}{(T_w - T)} = \frac{hA}{C_p \rho V} \int_0^t dt \tag{2}$$

Let the time taken for the air to flow past the pad media volume $t = \frac{V}{U}$, where V is the volume of the pad, u is the air flow rate, $A = H \times b, V = H \times b \times L$ and $u = Av$. L is the thickness of the pad media, b is the breath.

$$In\,\frac{(T_2 - T_w)}{T_1 - T_w} = -\frac{hHb}{C_p\rho HbLu}\int_0^V dV \tag{3}$$

Where:
T_2 [°C] - the temperature of cold air in the cooling space,
T_1 [°C] - the ambient air temperature.

$$In\,\frac{(T_2 - T_w)}{T_1 - T_w} = -\frac{hA}{C_p\rho u} \tag{4}$$

But $\frac{(T_2 - T_w)}{T_1 - T_w}$ is the evaporative effectiveness or efficiency (ε). Therefore:

$$In\varepsilon = -\frac{hA}{C_p\rho u} \tag{5}$$

and:

$$h = \frac{-C_p\rho u\; In\varepsilon}{A} \tag{6}$$

The average heat transfer coefficient can be calculated from the Eq. 6 considering the specific heat, and thermal conductivity of air is constant.

***Process modeling* (B)**

Also the heat transfer coefficient was fitted into the equation presented by Dowdy and Karabash (1987) [5]. Due to close packing of the pads, the pad was assumed to be rigid, therefore the heat transfer coefficient was calculated as:

$$N_u = \frac{h}{l} \tag{7}$$

Where:
Nu [-] - Nusselt number,
l [m^3] - characteristic length.

$$l = \frac{e}{A} \tag{8}$$

Where:
e [m^3] - the volume occupied by the pad.

$$N_u = 0.1\left(\frac{l}{x}\right)^{0.12} R_e{}^{0.8} Pr^{\frac{1}{3}} \tag{9}$$

Where:
X [m] - the thickness of the pad,
R_e [-] - Reynolds number.

$$R_e = \frac{v\,l}{V} \tag{10}$$

Where:
ν [m·s^{-1}] - air speed,
V [m^2·s^{-1}] - kinematic viscosity.

$$Pr = \frac{V}{\alpha} \tag{11}$$

Where:
Pr [-] - Prandtl number,
α [m^2·s^{-1}] - the thermal diffusivity which is given by:

$$\alpha = \frac{k}{\rho c_p} \tag{12}$$

The air mass flow rate was generated from the continuity equation as follows:

$$m_a = \rho A_1 v \tag{13}$$

Where A_1 [m] is the area of the pad covered by each of the three fans since the pad is divided into three compartments, each mounted with an axial fan of the same capacity controlled through a single gang switch of the same rheostat. The calculated value of some of the parameters used in the models is presented in Tab. 1 – 4.

Process modeling **(C)**

The heat transfer coefficient can also be calculated from the net change in the heat content of the air inside the cooler. The movement of the draft air through the wet pad results in the loss of heat. But the air inside the cooler usually picks up heat and moisture due to respiratory activities, there is a heat change also due to the incoming air at temperature T_2, replacing the air already inside the cooler at temperature T_b,. [12] stated that in this case change in enthalpy are proportional to temperature changes and considering the difference in temperature of the order involved, changes in their density and vapor pressure of the incoming and outgoing air are small and therefore negligible.

Therefore the energy equation can be written as:

$$H_i = uT_2\rho C_p \tag{14}$$

$$H_l = uT_b\rho C_p \tag{15}$$

Where u [m/s] is the air flow rate, H_i [J] is the heat input by the air coming into the cooler and H_l [J] is the heat loss by the air already inside the cooler. The air density (ρ) is taken to be constant.

Assuming no evaporation inside the cooling system and considering the low air flow rate of 0.6 m^3·s^{-1}, $T_b > T_2$ therefore the net heat gain by the incoming air is given by:

$$H_l - H_i = uT_b\rho C_p - uT_2\rho C_p \quad (16)$$

Because the other part of the evaporative cooling system is exposed to natural air motion, heat transfer through the walls and roof (h_{wr}) with area A_c, excluding the wet porous pad can be calculated from the general heat transfer equation as a function of wind speed [12] with an exchange coefficient h [W·m^{-2}K^{-1}] as follows:

$$h_{wr} = h(T_1 - T_b)A_c \quad (17)$$

The total energy balance equation for the evaporative cooling system can be written as:

$$dq = \rho c_p V\frac{dT}{dt} = h(T_1 - T_b)A_c + u\rho C_p(T_b - T_2) \quad (18)$$

Table 1. Values of constants used in the models

Symbol	Value	Unit	Equation
C_p	1005.0000	J·kg^{-1}K^{-1}	6,12 and 20
L	0.0300	M	3
H	1.0000	M	3
	0.6000	m^3·s^{-1}	3
p_r	0.7130	-	11
A	0.3000	m^2	6
A_c	1.7400	m^2	20
k	0.0260	W·m^{-1}K^{-1}	12

Table 2. Calculated properties of the air at day one

Time (h)	Re	Nu
9	3115	557
11	3096	557
13	3096	554
15	3090	554
17	3089	553

Table 3. Calculated properties of cold air at day two

Time (h)	Re	Nu
10	3103	555
11	3109	556
12	3115	557
13	3105	556
14	3078	551
16	3085	552
18	3095	554

Table 4. Calculated properties of cold air at day three

Time (h)	Re	Nu
10	3105	555
12	3109	556
14	3099	554
16	3067	550
18	3097	554

The time interval for the series of temperature measurement is assumed to be very short, the condition can be assumed to be steady state. Under steady state conditions $dT/dt = 0$ [12] and assuming $T_b \sim T_w$, substituting into Eq. 18, h can be calculated as:

$$h = \frac{-u\rho C_p(T_w - T_2)}{A_c(T_1 - T_w)} \quad (19)$$

The parameter $\frac{T_2 - T_w}{T_1 - T_w}$ is the evaporative effectiveness or efficiency, therefore Eq. 19 can be rearranged to give:

$$h = \frac{u\rho C_p (T_2 - T_w)}{A_c (T_1 - T_w)} \tag{20}$$

Relaxation time

In Heat Transfer, it is interesting to know the finite-time process, and a basic question is to know the thermal inertia of the system, i.e. how long the heating or cooling process takes under the tested conditions, usually with the intention to modify it, either to make the system more permeable to heat, more insulating, or more 'capacitive', to retard a periodic cooling/heating wave. For the case where the heat flux is not imposed but a temperature gradient is imposed, an order-of-magnitude analysis of the energy balance, shows that depending on the dominant heat-transfer mode the relaxation time is of the order [13]:

$$\frac{dH}{dt} = q \tag{21}$$

$$\Delta H = mc\,\Delta T \tag{22}$$

For a process dominated by heat transfer by convection like evaporative cooling process where the change in temperature of the ambient air and cold storage space temperature is given as ΔT:

$$q = \mathrm{hA}\,\Delta\mathrm{T} \tag{23}$$

Considering a wet porous pad of characteristic length l which is at the same temperature with the cold air inside the cooler at density ρ and assuming that the relaxation time is proportional to l.

$$\Delta t = \frac{\Delta H}{q} = \frac{mc_p \Delta T}{hA\Delta T} = \frac{\rho c_p l^3}{h l^2} = \frac{\rho c_p l}{h} \tag{24}$$

Note that *m* is the mass [kg], l is the characteristic length given as $\frac{V}{A}$ and $m = \rho V$.

The above equation can be used to hypothetically guess the relaxation time of the system although this might not be a realistic value but gives the maximum time required since the value is usually predicted at a little above the mid temperature of the hot and cold temperature [13].

Statistical analyses

Minitab 1513 was used to analyze the results of the fitted models. The value of *h* was fitted using the method of least square. R^2 value and standard deviation was used to assess the goodness of fit.

RESULTS AND DISCUSSION

Direct measurement from the experiment conducted yielded the ambient air temperature, the process air temperature, wet bulb temperature and the air flow rate used to obtain the heat transfer coefficients, temperature and relative humidity profile of the wet porous pad at each experimental condition (Fig. 2 - 7). The parameters used in the equation and the constant values were presented in Tab. 1 - 4. The dimensions of the wet porous pad used for the analysis were A = 0.30 m^2, A_c = 1.74 m^2 and V = 0.009 m^3. The value of air flow rate tested is 0.6 $m^3 \cdot s^{-1}$ and for the wet porous pad of the dimension specified this is equivalent to ventilation rate of 0.0056 $m^3 \cdot m\text{-}^2 s\text{-}^1$ and to approximately 8 air changes per hour. According to [12], higher ventilation rate improves the efficacy of cooling (lower temperature) but the improvement is non linear but has to be balanced with high cost of power and fan associated with increased fan capacity and also the high relative humidity needed for the storage space. Therefore the research evaporative cooling system was designed for low ventilation rate because, the targeted users of the system are rural dwellers, who are very poor and cannot afford the high cost of increased fan capacity. Also the temperature reduction and relative humidity achieved can maintain the quality of their produce in a short period at which they can sale their produce with minimum loss.

Simulation commenced at 7.00 hrs local time and proceeded in time steps of 2 hrs to 18.00 hrs local time corresponding to a day length of 11 hrs. In modeling with Eq. 6 and 7 the heat transfer is considered as depending partly on the characteristics of the wet porous pad and the flow of air into the system is only through the wet porous pad. However in Eq. 20 the whole enclosure is treated as porous material surrounded by air driven by the wind since the system is also exposed to the wind. The heat transfer is both through the wet porous pad and the walls of the enclosure. Representative curves showing the variation of heat transfer coefficient, derived from simulation runs for the three equations are presented in Fig. 2, 3 and 4. The variation of temperatures and relative humidity through the day is also presented in Fig. 5, 6 and 7. For day one the maximum ambient air temperature of 34°C occurred at 15.00 hrs local time, for day two, it was 34.8°C at 16.00 hrs and 34°C for day three at also 16.00 hrs. The results presented here showed that the single stage evaporative cooler can reduce the ambient air temperature by 13°C under high ambient temperature which usually results in high radiation intensity. The average heat transfer coefficients were calculated by fitting the evaluation parameters into Eq. 6, 7 and 20. The results obtained are higher for higher evaporative effectiveness for Eq. 20 and 7 but decreased for Eq. 6 at higher evaporative effectiveness for the three days period. It is observed from the equations that if the evaporative effectiveness is constant, the heat transfer coefficient will be constant since it directly or indirectly controls the parameters in the equations. Large standard deviations (130.94 – 282.85) obtained for the three days period for Eq. 6 compared to Eq. 20 (17.53- 26.3) and Eq. 7 (1.87 -1.99) might be because of small area for heat transfer and steep temperature drop in the afternoon compared to the morning period. Eq. 7 has been widely used by some authors [14, 4 and 15] to predict heat transfer coefficient in evaporative coolers and the results has been compared with experimental values with good results. Therefore Eq. 7 was used to test the level of accuracy of Eq. 6 and 20. The values obtained in Eq. 7 are very close to Eq. 20 with a maximum value of

483 and 396 respectively; therefore Eq. 20 can provide an alternative route for quick calculation of heat transfer coefficient in evaporative cooling because it contains less number of parameters to calculate than Eq. 20.

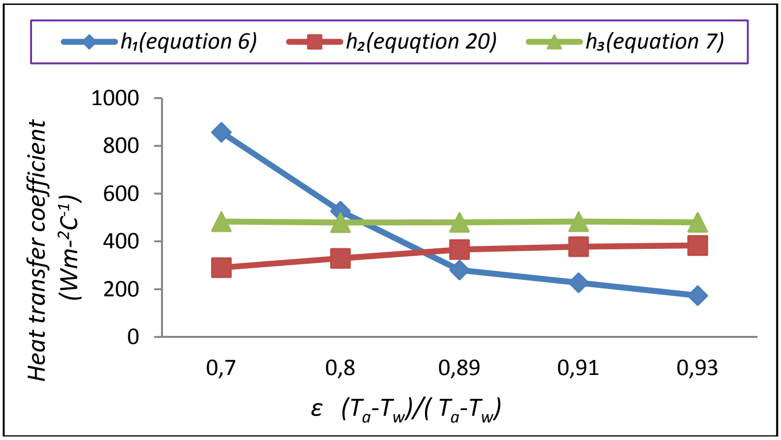


Figure 2. Heat transfer coefficient curve for day one

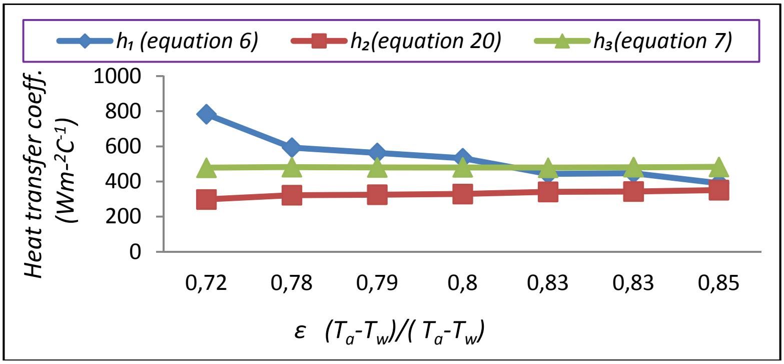


Figure 3. Heat transfer coefficient curve for day two

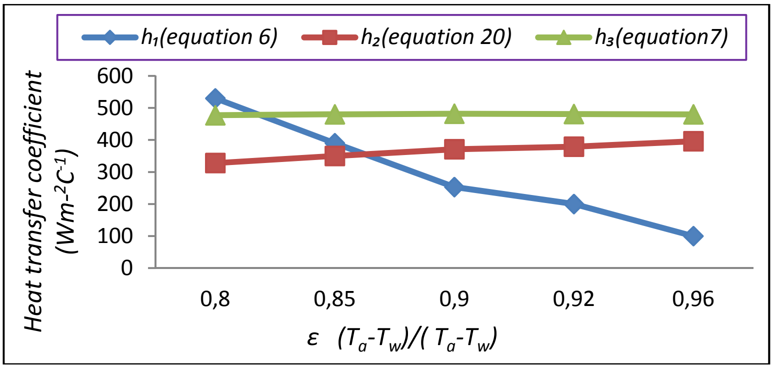


Figure 4. Heat transfer coefficient curve for day three

Result of relationship of h with ambient air temperature (T_1) and R^2 value derived by the method of least square is presented in Tab. 5. The various relationship for the three days showed that, h_1 has an exponential relationship with ε; h_2 has a linear relationship with ε while h_3 has a polynomial relationship with ε. Generally the R^2 value for various equations is above 90%.

Table 5. Relationship between heat transfer coefficient and evaporative effectiveness [$\varepsilon = (T_c - T_w)/(T_1 - T_w)$]

Day	h	Model	R^2
1	h_1	$h_1 = 1163e^{-40\varepsilon}$	0.959
	h_2	$h_2 = 23.5\varepsilon + 278.7$	0.895
	h_3	$h_3 = -0.916\varepsilon^3 + 8.54\varepsilon^2 - 23.54\varepsilon + 499$	0.974
2	h_1	$h_1 = 791.5e^{-0.10\varepsilon}$	0.928
	h_2	$h_2 = 7.75\varepsilon + 298.8$	0.911
	h_3	$h_3 = -0.02\varepsilon^5 + 0.337\varepsilon^4 - 1.623\varepsilon^3 + 1.291\varepsilon^2 + 6.522\varepsilon + 4715$	0.756
3	h_1	$h_1 = 842.3e^{-0.4\varepsilon}$	0.970
	h_2	$h_2 = 16.5\varepsilon + 315.3$	0.976
	h_3	$h_3 = 0.785\varepsilon^2 + 5.44\varepsilon + 472.4$	0.967

The relaxation time based on the various heat transfer coefficients calculated from Eq. 6, 7 and 20 is presented in Tab. 6, 7 and 8 for the period of three days. The average value for the three equations is approximately one second which shows consistency although Eq. 7 gave a constant value of 0.75 s. The value predicted from the equations can be regarded as a hypothetical value since other heat transfer methods like conduction or even radiation loss can contribute to the cooling of the air. Therefore the value calculated might be much higher than the real relaxation time. This value can serve as a basis in future design or modification of the system and its kind.

Table 6. Relaxation time for the process ambient air for day one at various heat transfer coefficient

Time (h)	Eq. 6	Eq. 7	Eq. 20
	t_1 (s)	t_2 (s)	t_2 (s)
9	0.42	0.75	1.20
11	1.58	0.74	0.95
13	1.07	0.75	0.94
15	1.28	0.75	0.98
17	0.68	0.75	1.00
Average value	1.00	0.75	1.01

The temperature and relative humidity profile is presented in Fig. 5, 6 and 7 for the period of three days. Considering the flowing of humid air to the wet porous pad, the heat transfer will occur if the surface temperature of the pad is different from the draft ambient air temperature. Also mass transfer will occur if the absolute humidity of the air close to the pad is different from the humidity of the draft ambient air [15].

Table 7. Relaxation time for the process ambient air for day two at various heat transfer coefficient

Time (h)	Eq. 6	Eq. 7	Eq. 20
	t_1 (s)	t_2 (s)	t_2 (s)
10	0.67	0.75	1.09
12	0.92	0.75	1.02
14	0.46	0.75	1.20
16	0.81	0.75	1.05
18	0.64	0.75	1.10
Average value	0.71	0.75	1.09

Table 8. Relaxation time per hour for the process ambient air for day three at various heat transfer coefficient

Time (h)	Eq. 6	Eq. 7	Eq. 20
	t_1 (s)	t_2 (s)	t_2 (s)
10	1.79	0.75	0.95
12	1.42	0.75	0.97
14	3.58	0.75	0.91
16	0.67	0.75	1.09
18	0.92	0.75	1.02
Average value	1.68	0.75	0.99

The temperature and humidity profile of the storage space showed a decrease and increase of the ambient air temperature and relative humidity respectively. It is clear from Fig. 5 that at 13:00 hours, the ambient air of 32.8°C with 36 % relative humidity could be brought to 23.2°C and 90.4 % relative humidity at the first day. It shows that the system can drop the ambient air temperature very close to its wet bulb temperature of 21.96°C. The maximum temperature reduction observed was 13°C. The relative humidity of the cooler was observed around 85.6 - 96.8 % throughout the experiment, which shows the maximum possible level of saturation of air by humidification.

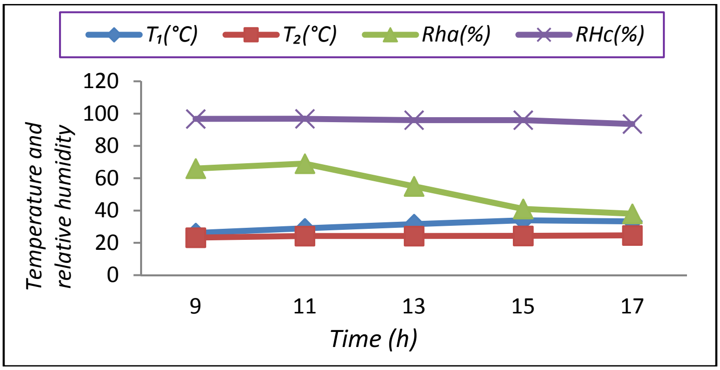


Figure 5. Temperature and relative humidity profile for day one

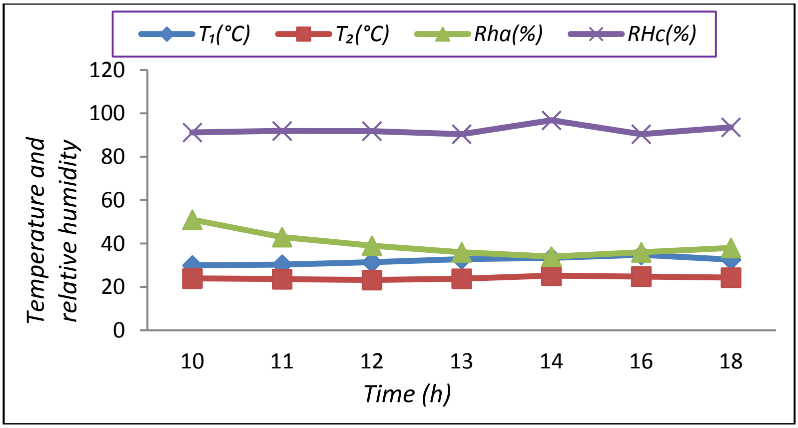


Figure 6. Temperature and relative humidity profile for day two

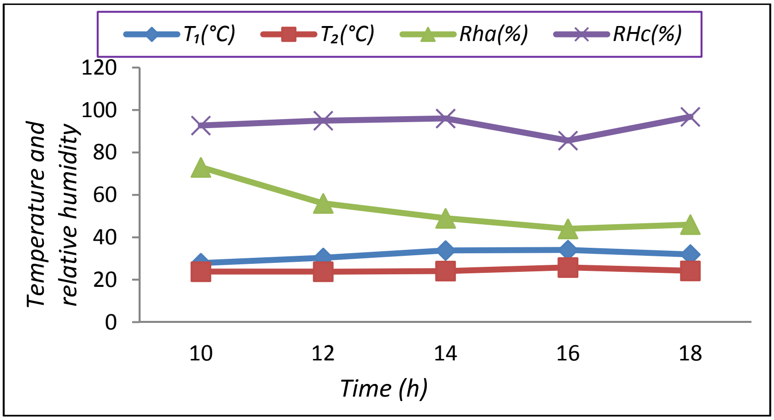


Figure 7. Temperature and relative humidity profile for day three

CONCLUSION

The equations for modeling heat and mass transfer can be used to predict process fluid behavior with temperature under different ambient conditions for direct evaporative cooling systems. This information is a valuable tool for designing and also modifying already existing evaporative cooling systems. Models were obtained for heat transfer and relaxation time and can be applied to different situation in heat and mass transfer process. Generally the temperature and relative humidity profile of the system showed that greater cooling is achieved in the afternoon. This is desirable since the afternoon presents higher heat load therefore requires more cooling to maintain the cooler condition at the desired temperature and humidity state. The maximum temperature reduction during the field evaluation was 13°C with the relative humidity of the cooler ranging from 85.6 – 96.8 % throughout the experiment, which shows the maximum possible level of saturation of air by humidification.

BIBLIOGRAPHY

[1] Xuan, Y.M.F., Xiao, X.F., Niu, X., Huang, S.W. 2012. Research and application of evaporative cooling in China: A review (I). *Renewable and Sustainable Energy Reviews*Volume 16, Issue 5, June , pp 3535 – 3546

[2] Gupta, C.P.A., Abbas, M.S. 1995. Thermal comfort inside a tractor cab by evaporative cooling system. *Transaction of ASAE* 38(6): 1667-1675.

[3] Liao, C., Chiu, K. 2002. Wind Tunnel Modeling the System Performance of Alternative Evaporative Cooling Pads in Taiwan Region. *Building and Environment*, p. 177-187

[4] Camargo, J.R., Ebinuma, C.D., Cardoso, S. 2003. A mathematical model for direct evaporative cooling air conditioning system. *Engenharia Térmica,* no.4,p. 30-34

[5] Dowdy, J.A., Karabash, N.S. 1987. Experimental Determination of Heat and Mass Transfer Coefficients in rigid Impregnated Cellulose Evaporative Media. *ASHRAE Transactions,* part 2, vol. 93. pp. 382-395.

[6] Ditchfield, C. C.C., Tadini, R.K., Singh, R.T. 2006. Velocity and temperature profile, heat transfer coefficient and residence time distribution of temperature dependent Herschel bukly fluid in tubular heat exchanger. *Journal of food engineering* (79), 632 -638

[7] Peterson, J.L. 1993. An effectiveness model for indirect evaporative coolers. *ASHRAE Transactions*; 99(2).

[8] Ren, C.Q., Yang, H.X. 2006. An analytical model for heat and mass transfer processes in indirect evaporative cooling with parallel/counter flow configurations. *Int. J. Heat and Mass Transfer*, 49 .pp. 617–627

[9] Wu, J.M., Huang, X., Zhang, H. 2009. Theoretical analysis on heat and mass transfer in a direct evaporative cooler. *Applied Thermal Engineering*, 29 (5–6), pp. 980–984

[10] Ndukwu M.C, Manuwa, S.I. Olukunle, O.J., Oluwalana, I.B. 2013. Development of an Active Evaporative Cooling System for short-term storage of tropical agricultural product. Agricultural engineering international. *The CIGR Journal* 15(4) 307-313.

[11] Wat, J.R., Brown, W.K. 1997. *Evaporative air conditioning handbook* (3rd ed.)The Fairmont Press, USA (1997)

[12] Landsberg, J.L., White, B., Thorpes, M.R. 1979. Computer analysis of the efficacy of evaporative cooling for glasshouse in high energy environment. *Journal of agricultural engineering research* 24, pp 29-39.

[13] Isidoro, M. 2013. *Heat and Mass Transfer*. Politecnica.

[14] http://webserver.dmt.upm.es/~isidoro/bk3/c12/Heat%20convection.%20Boundary%20layer%20flow.pdf. Downloaded 4th December 2013.

[15] Qureshi, B.A., Zubair, M. 2006. A comprehensive design and rating study of evaporative coolers and condensers. Part I. Performance evaluation: *International Journal of Refrigeration,* 29, pp 645–658

[16] Ghasem, H. 2008. Heat and mass transfer modeling of two stage indirect/direct evaporative air coolers: ASHRAE Thailand Chapter.*ASHARE Journal* 2007 – 2008 .Pp 2-8

KOEFICIJENT PRENOSA TOPLOTE I KONCEPT PERIODA RELAKSACIJE U SISTEMU EVAPORATIVNOG HLAĐENJA PRINUDNO USMERENIM VAZDUHOM

Ndukwu M.Chinenye[1, 2], Seth.I.Manuwa[2]

[1]*Poljoprivredni univerzitet Michael Okpara Umudike, Institut za inženjering poljoprivrede i bioresursa, Umuahia, Abia State, Nigerija*
[2]*Federalni tehnološki univerzitet Akure, Istitut za poljoprivrednu tehniku, Akure Ondo State, Nigerija*

Sažetak: Sistem evaporativnog hlađenja sa rashladnim uloškom od palminih vlakana je bio ispitivan pri različitim temperaturama i relativnim vlažnostima vazduha. Ogled je izveden sa prototipom direktnog sistema evaporativnog hlađenja za zaštitu voća i povrća od umerene respiracije sa niskim protokom od 0.6 $m^3 \cdot s^{-1}$. Ponuđena su tri različita modela za postizanje koeficijenta prenosa toplote pri različitim efikasnostima evaporacije. Za ova tri modela, koeficijent prenosa toplote varirao je od 173 do 857 $W \cdot m^{-2} K^{-1}$. Period relaksacije bilo je predviđeno kao konačan vremenski proces i vrednost izračunata iz modela može se prihvatiti kao hipotetička, obzirom da su drugi postupci prenosa toplote, kao provođenje ili čak i radijacioni gubici, bili zanemareni. Zato izračunata vrednost može da bude mnogo veća nego stvarni period relaksacije. Za opseg ambijentalnih temperature od 26.1 do 34.8°C, koje su hlađene na 23.2 do 25.8°C, za srednji period relaksacije bile su izračunate vrednosti od 0.71 do 1.68 s.

Ključne reči*: ambientalna temperature, evaporativno hlađenje, prenos toplote, relativna vlažnost*

Prijavljen: *Submitted*:	06.03.2014.
Ispravljen: *Revised*:	20.09.2014.
Prihvaćen: *Accepted*:	24.09.2014.

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

631(059)

ПОЉОПРИВРЕДНА техника : научни часопис = Agricultural engineering : scientific journal / главни и одговорни уредник Горан Тописировић. – Год. 1, бр. 1 (1963)- . - Београд; Земун : Институт за пољопривредну технику, 1963- (Београд : Штампарија ”Академска издања”) . – 25 cm

Тромесечно. – Прекид у излажењу
од 1987-1997. године
ISSN 0554-5587 = Пољопривредна техника
COBISS.SR-ID 16398594