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PREFACE

In the name of the Comittee of Agricultural and Biosystem Engineering of the Hungarian Academy of Sciences we would like to welcome everyone who is interested in reading our journal. The Hungarian Agricultural Engineering (HAE) journal was published 29 years ago for the very first time with an aim to introduce the most valuable and internationally recognized (in these years already DOI numbered) Hungarian studies about mechanization in the field of agriculture and environmental protection. Initially the "Hungarian Institute of Agricultural Engineering" was responsible for the publication of the magazine which was mostly based on the articles and the presentations of the annually organized International Mechanization Conference. Later on – thanks to these international meetings – we were able to publish the researches of experts from different international universities. Basically we used the printed paper form to publish our journal and distributed it amongst the libraries of well-known Hungarian and international research centers and everyone who subscribed for it. In the year of 2014 the drafting committee decided to spread it also in electronic (on-line) edition and make it entirely international. After that the Szent István University's Faculty of Mechanical Engineering took the responsibility to publish the paper in cooperation with the Hungarian Academy of Sciences. Our goal is to occasionally report the most recent researches regarding mechanization in agricultural sciences (agricultural and environmental technology and chemistry, livestock, crop production, feed and food processing, agricultural and environmental economics and energy) with the help of several authors. The drafting committee has been established with the involvement of outstanding Hungarian researchers who are recognized on international level as well. All papers have been selected by our editorial board and double blind reviewed by prominent experts, which process could give the highest guarantee for the best scientific quality. We hope that our journal provides with accurate information for the international scientific community and serves the aim of the Hungarian agricultural and environmental engineering research and development - from 2015 twice a year.

Gödöllő, 30.12.2016.

Dr. István SZABÓ
editor in chief

Dr. László TÓTH
editor in chief

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THE APPLICATION OF AHP IN SRID EVALUATION FRAMEWORK OF CHINESE AGRICULTURAL ENTERPRISE

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Abstract

The Analytic Hierarchy Process (AHP) has been invented by SAAS, and has been applied in many fields [1]. It is very helpful in complex problem for the decision makers. And the AHP divides the decision goal into many factors, and each factor contains various decision choices. Through the comparison of the elements (factors and choices) in the AHP, the decision makers can build the comparison matrix. And through computing the Eigen vector and Eigen value, the decision makers can get the weights of all the elements and make the decision which best suits the problem.

This paper wants to apply this AHP to the SRID evaluation framework[1] of agricultural enterprises which is constructed by Maohua Li (2016) [2]. Though Maohua Li (2016) builds the SRID evaluation framework of agricultural enterprises, how to apply this framework to the real agricultural enterprises is a problem. This paper attempts to use the analytic hierarchy process to solve this problem, and tries to give the corresponding weights to each item (factor and choice) in this framework, so as to ensure the consistency of the weighting process and the integrity of the framework. Through this study, the SRID framework of agricultural enterprise can be used smoothly in various agricultural enterprises. It can help to understand the quality of SRID of agricultural enterprises better.

Keywords

AHP, CSR, information disclosure, evaluation framework.

[1]The model is constructed by Maohua Li in the paper "Study on the SRID Evaluation Framework of Agricultural Enterprise in China" which is published by the journal "Visegrad Journal on Bioeconomy and Sustainable Development" in 2016, vol.5, issue 1, pp.36-40.

Introduction

The corporate social responsibility (CSR) refers to the responsibility that the enterprise should take as a kind of social organization [3]. It is the responsibility in the process of production and operation of the enterprise. It includes the economic and social responsibility of business to consumers, employees, shareholders, the community, the government and the environment. The purpose of corporate social responsibility is to "give humanism to the market economy", and to stress that enterprises should bear the responsibility for the environment and stakeholders while making profits [4].

CSR means that corporate is not only responsible to the stockholders, but also takes responsibility to the other stakeholders [5, 6]. It contains social responsibility and social obligation, and the content contains business ethics, production safety, occupational health, protection of legitimate rights and interests of workers, protection of the environment, the charity support, the community donation, the protection of vulnerable groups, etc [7].

In the market economy, the competitiveness of enterprises is the outstanding performance of the ability to pursue profits [8]. Profit is the reason for the existence of enterprises and the fundamental driving force of the development. However, CSR is the foundation of sustainable development and the tool for the long-term profit.

In Hungary, Nagypál N. C. (2014) uses Hungarian SME as research sample and he finds that corporate social responsibility plays a very important role in the sustained development [9]. Radacsi G. and Hardi P. (2014) point out that CSR is a voluntary add-on to the regular market activities and legal compliances of companies [10]. Metaxas T. and Tsavdaridou M. (2010) make a detailed research on the dimensions and benefits of CSR in Greece, Denmark and Hungary, and they get the conclusion that the effective implementation of CSR strategy cannot follow strict rules and should be adjusted to the culture, needs and particularities of each country [11].

However, enterprises will interact with other social organizations and individuals frequently in this social system [12]. In the process of interaction, many ethic risks will occur due to externality and asymmetric information. And there are many conflicts between profit of corporate and interest of society which may have impact on the staff and society [13]. For the prosperity and harmony of the society, we have the reason to promote the enterprise to strengthen the social responsibility, and to increase the disclosure of social responsibility information (SRID).

There are many problems on SRID, such as information disclosure is incomplete; the form of information disclosure is single [14]; the comparability of information disclosure is not strong; the carrier of information disclosure is less. How to evaluate SRID is a problem, in this case, Maohua Li (2016) proposes a SRID evaluation framework. This framework includes four elements: content quality, total quality, expression and utility quality. However, he does not study on how to apply this framework. This paper attempts to use the Analytic Hierarchy Process (AHP) to solve this problem, and tries to give the corresponding weight to each item in this framework, so as to ensure the consistency of the weighting process and the integrity of the framework. Through this study, the SRID framework of agricultural enterprise can be used smoothly in various agricultural enterprises. It can help to understand the quality of SRID of agricultural enterprises better.

2. Literature review

In 1953, Howard R. Bowen first proposes that business owners have the responsibility to meet all of the mainstream values and public needs, so he is called the father of corporate social responsibility. In his book, "Social Responsibilities of the Businessman", he points out that shareholders, employees, consumers, government, community, etc. are stakeholders of enterprises, and enterprises should not only attain the goal of stockholder, but also should make some contributions to the other stakeholders [15].

Scholars also make some achievements in the social responsibility information disclosure (SRID). Andrew Crane, in his book "Corporate Social Responsibility", talks about SRID based on the use of value-added sheet [16]. Toni, in his book "Social Responsibility Accounting", mainly discusses the background of the social responsibility accounting, expounds the connotation of social responsibility accounting and has a profound discussion on SRID [17].

On the evaluation of CSR, Li Yongchen and Cao Xi (2013) researches on the social responsibility evaluation index system of power supply enterprises [18]. Hu Junnan Meng Dandan (2015) uses AHP to do a research of industrial projects investment evaluation based on the social responsibility [19]. Huang Yifang and Sun Yongbo (2015) uses AHP method to do research on the social responsibility evaluation index system of retail enterprise [20].

In Hungary, as we mentioned above, there only a few scholars make research on CSR in English, such as Nagypál N. C., Radacsi G., Hardi P., Metaxas T., and Tsavdaridou M. They get some research results from different perspectives. Nagypál N. C. (2014) makes some research on CSR from the point of SME [8]. Radacsi G. and Hardi P. (2014) point out the function of CSR in market activities. Metaxas T. and Tsavdaridou M. (2010) make research on the CSR in Europe with the samples of Greece, Demark and Hungary [11]. However, No Hungarian scholar makes any research on the evaluation of SRID as we search.

Although many scholars make a great progress on the research of CSR and SRID, nobody focuses on how to evaluate SRID. Maohua Li (2016) use oral theme encoding method to construct the SRID evaluation framework of agricultural enterprises for the first time, and he uses the expert opinion method and factor analysis method to verify the framework.

3. SRID evaluation framework

Table 1. SRID evaluation framework

First-Level	Second-Level	Third-Level
SRID Evaluation Framework A	Content quality B_1	Objectivity C_{11}
		Correctness C_{12}
		Credibility C_{13}
	Total quality B_2	Relevance C_{21}
		Completeness C_{22}
		Sufficiency C_{23}
	Expression quality B_3	Definition C_{31}
		Intelligibility C_{32}
		Conciseness C_{33}
	Effectiveness quality B_4	Timeliness C_{41}
		Adaptability C_{42}
		Testability C_{43}

Maohua Li (2016) establishes the SRID evaluation framework of agricultural enterprises through the method of the oral theme encoding technology, the frequency analysis, the reliability test and so on. And the expert opinion method, exploratory factor analysis and confirmatory factor analysis are used to verify the evaluation framework. According to Maohua Li (2016), the SRID evaluation framework of agricultural enterprises consists of four elements and 12 specific indicators. Details are shown in the bellowing Table 1.

4. About AHP

The analytic hierarchy process (AHP) treats the complex multi-objective decision as a system, and divides the purpose of it into several targets or factors which can be divided into multiple objectives or choices. AHP can help decision maker get a rational and comprehensive solution to the complex decision problem. Instead of providing a "correct" answer to the problem, the AHP will help the decision makers to get the solution which is the most suitable to the complex problem and help the decision makers to understand the problem better.

Just like the Figure 1, AHP will divide the goal of decision into several factors which contain various choices. The factors and choices are related to every aspect of the decision that contains tangible and intangible problems. All the factors will be well understood and carefully measured and they are divided into various choices that apply to the decision at hand.

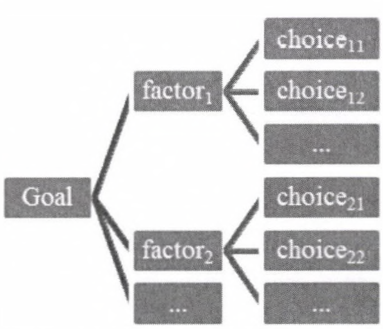

Figure 1. Structure of AHP

Once the structure of AHP is fixed, the decision makers only have to consider the impact of choices to factors or the impact of factors to the goal, and then evaluate all the choices and factors systematically by comparing them to each other. For instance, in the process of comparing choices, the decision makers can consider the importance of choices to its own factor and evaluate them. And the same method can be used in comparing the factors according to the impact of them to the goal.

5. Weights of SRID evaluation framework based on AHP

In the actual weighting process of SRID evaluation framework, we can use the relatively simple method to weight, and the main steps are as follows:

To form the comparison matrix A according to the scores of different estimators.

$$A=\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

The product B_i of each-row elements of the comparison matrix A is calculated.

$$B_i=\prod_{j=1}^{n} a_{ij}$$

$$i=12\ldots n$$

To compute the n-th root C_i of B_i

$$C_i=\sqrt[n]{B_i}$$

$$i=12\cdots n$$

To normalize the vector $C=(C_1, C_2, \quad C_n)$

$$W_i=\frac{C_i}{\sum_{i=1}^{n} C_i}$$

$$i=12\cdots n$$

$W=(W_1, W_2, \quad W_n)^T$ is the Eigen vector that we need, and the Eigen values $W_1, W_2, \quad W_n$ are the weights of every row.

In order to ensure the correctness of the results, the consistency test is carried out. In the process of constructing the comparison matrix, the subjective consciousness of the estimators is very strong. Therefore, it is necessary to use consistency test and consistency ratio to determine the compatibility of the weight, and to evaluate the reliability of comparison matrix. The calculation steps are as follows:

To calculate the consistency index CI

$$\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n}\frac{\sum_{j=1}^{n} a_{ij}W_j}{W_i}$$

and

$$CI=\frac{\lambda_{\max}-n}{n-1}$$

The largest Eigen value is called the principal Eigen value, and λ_{max} is the largest Eigen value of comparison matrix, and n is orders of the comparison matrix $A=(a_{ij})_{nxn}$.

To calculate the consistency ratio CR

$$CR=\frac{CI}{RI}$$

In the formula above, RI is the average random consistency index, and its value can be obtained by looking up the related Table 2. If $CR < 0.1$, we can accept the consistency, that is to say, the consistency test of comparison matrix is passed. If $CR \geq 0.1$, we should make appropriate adjustments to comparison matrix A.

Table 2. Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: [21]

Now we set an illustrative example about how to weight the SRID evaluation framework of agricultural enterprise based on the AHP.

There are fore estimators such as market supervisor, competitor, supplier, purchaser, and they will estimate the SRID framework separately and form a comparison matrix A.

$$A = \begin{pmatrix} 1 & 4 & 3 & 1 \\ 1/4 & 1 & 2 & 1/4 \\ 1/3 & 1/2 & 1 & 1/3 \\ 1 & 4 & 3 & 1 \end{pmatrix}$$

According to matrix A, we can calculate $B_1 = 12$. $B_2 = 1/8$. $B_3 = 1/18$. $B_4 = 12$

To calculate the n-th root C_i of B_i

C_1=1.8612. C_2=0.5946. C_3=0.4855. C_4=1.8912

To normalize the vector C=(1.8612, 0.5946, 0.4855, 1.8912), we can get that

W_1=0.3875. W_2=0.1238. W_3= =0.1012. W_4=0.3875

And then to calculate the consistency index CI:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{\sum_{j=1}^{n} a_{ij}W_j}{W_i}$$

=4.089;

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{4.089-4}{4-1} = 0.0297$$

Due to N=4, the value of RI=0.9 which can be obtained by looking up the related Table 2.

So

$$CR = \frac{CI}{RI} = \frac{0.0297}{0.9} = 0.033 < 0.1,$$

The CR of comparison matrix can be accepted.

That is to say that the weights of them are as follows in Table 3:

Table 3. Sample of weighting

valuator	Market supervisor	competitor	supplier	purchaser
weight	0.3875	0.1238	0.1012	0.3875

Table 4. The weighting results of SRID evaluation framework

First-Level	Second-Level	Weight	Third-Level	Weight
SRID Evaluation Framework A	Content quality B_1	0.2968	Objectivity C_{11}	0.3122
			Correctness C_{12}	0.5124
			Credibility C_{13}	0.1754
	Total quality B_2	0.2437	Relevance C_{21}	0.3862
			Completeness C_{22}	0.3227
			Sufficiency C_{23}	0.2911
	Expression quality B_3	0.1962	Definition C_{31}	0.3124
			Intelligibility C_{32}	0.3472
			Conciseness C_{33}	0.3404
	Effectiveness quality B_4	0.2633	Timeliness C_{41}	0.2532
			Adaptability C_{42}	0.4201
			Testability C_{43}	0.3267

According to the similar method above, we can calculate the weights of the four elements such as content quality, total quality, expression quality and effectiveness quality. And then we can calculate the weights of the indicators. The weighting results are shown in the Table 4.

According to Table 4, we can make the weight calculation table (Table 5) of the SRID evaluation framework.

Table 5. Weight calculation table of the SRID evaluation framework

B_1(0.2968)		Proportion of C_1 among A	B_2(0.2437)		Proportion of C_2 among A
C_{11}	0.3122	0.0927	C_{21}	0.3862	0.0941
C_{12}	0.5124	0.1521	C_{22}	0.3227	0.0786
C_{13}	0.1754	0.0521	C_{23}	0.2911	0.0709
B_3(0.1962)		Proportion of C_3 among A	B_4(0.2633)		Proportion of C_4 among A
C_{31}	0.3124	0.0613	C_{41}	C_{31}	0.3124
C_{32}	0.3472	0.0681	C_{42}	C_{32}	0.3472
C_{33}	0.3404	0.0668	C_{43}	C_{33}	0.3404

Through the analysis above, we can construct the SRID evaluation framework as follows:

$$Y_{ji} = \sum_{i=1}^{i=3} X_{ji} \bullet w_{ji}$$

$$F = \sum_{k=1}^{k=n} (\sum_{j=1}^{j=4} Y_j \bullet W_j) P_k$$

$$i=123$$

$$j=1234$$

$$k=12\cdots n$$

F is the score of SRID evaluation framework (from 1 to 5)

X_{ji} is the score of third-level (from 1 to 5)

Y_{ji} is the score of second-level (from 1 to 5)

w_i is the weight of third-level

W_j is the weight of second-level

P_k is the score by the grader k (from 1 to 5)

By the total score of SRID evaluation framework of the agricultural enterprise, we can tell the grade of its SRID and can tell the quality of its SRID (Table 6.).

Table 6. Grade standard of the scoring

Range of score	5	4	3	2	1
Grade	excellent	good	satisfactory	sufficient	insufficient

6. Conclusion

By trying to use the AHP method, this paper gives the weight of each evaluation item in the SRID evaluation framework of agricultural enterprise, so as to ensure the application of the SRID evaluation framework in agricultural enterprises and the integrity of the framework. Through the application of the evaluation framework based on the AHP method, we can get more accurate, objective and convincing results from the evaluation of social responsibility information disclosure.

And the evaluation framework mixes the advantages of expert opinion method, fuzzy comprehensive evaluation method and AHP method, so we get a more objective and comprehensive result than the previous single evaluation methods. On the basis of the comprehensive evaluation framework to evaluate the SRID, we can find their own problems, and find technique to solve them. So through the evaluation framework based on AHP method, we can evaluate the SRID correctly and tell the quality of SRID of agricultural enterprises.

In Hungary, this paper only focuses on related research of CSR, SRID and the evaluation of SRID in English. In the future research, we will extend our research in Hungarian with local scholars.

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INFLUENCING OF SOLAR DRYING PERFORMANCE BY CHIMNEY EFFECT

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Abstract

The aim of this paper to study effect of a chimney installed in solar drying system. A chimney is device usually used to remove the air to the atmosphere. Free convection is obtained with using a chimney which permits to have a good air speed by free convection and homogeneous distribution of the heated air inside the drying chamber. It allows also having better control of the drying process.

The greenhouse effect achieved within the collector drives the air flow through the drying chamber. The hot air rises and escapes through the upper vent in the drying chamber (chimney) while cooler air at ambient temperature enters through the lower vent in the collector. Therefore, an air flow is maintained, as cooler air enters through the lower vents and hot air at a temperature leaves through the upper chimney vent.

Keywords

balance equation, control, convection, design, solar collector

1. Introduction

The use of the solar energy is getting a greater importance in the agriculture as because of the growing energy prices and the importance of the environment protection. At the same time the quality control and quality preservation becomes also more and more important items for processing of agricultural products. A traditional and very widely used product preservation is the drying. Main drawbacks of drying are the relatively high energy consumption and changing product properties during the heat and de-watering treatment. However, the attractiveness of drying methods can be improved by using advanced control and optimization techniques for reducing the energy consumption [1].

The chimney itself is the plant's actual thermal engine in most of the solar dryers using natural ventilation effect. It is a pressure tube with low friction loss (like a hydroelectric pressure tube or penstock) because of its optimal surface-volume ratio. The up thrust of the air heated in the collector is approximately proportional to the air temperature rise ΔTcollector in the collector and the volume of the chimney. In a large solar chimney the collector raises the temperature of the air by about 35 K. This produces an up draught velocity in the chimney of about 15m/s. It is thus possible to enter into an operating solar chimney plant for maintenance without difficulty. Chimneys 1,000 m high can be built without difficulty. The television tower in Toronto, Canada, is almost 600 m high and serious plans are being made for 2,000 metre skyscrapers in earthquake-ridden Japan. But all that is needed for a solar chimney is a simple, large diameter hollow cylinder, not particularly slender, and subject to very few demands in comparison with inhabited buildings. There are many different ways of building this kind of chimney. They are best built freestanding, in reinforced concrete. But guyed tubes, their skin made of corrugated metal sheet, as well as cable-net designs with cladding or membranes are also possible. All the structural approaches are well known and have been used in cooling towers. No special development is needed.

The principle of the solar chimney effect is a combination of solar stack-assisted and wind-driven ventilation. Air in the chimney expands due to solar heating and being relatively lighter, rises out of the chimney outlets, drawing the cooler air into the interior through the fenestrations. This pull effect is further complemented by the push effect from the ambient wind. The stack pressure difference driving the air movement is a combination of the different densities between the interior and ambient environment as well as the stack height where the greater the stack height and temperature difference, the stronger the pressure difference. In solar assisted stack ventilation, the temperature difference is achieved from heat gained due to solar irradiance. Research has determined the operability of implementing solar chimneys in the hot, cloudy and humid tropics. This paper aims to discuss the performance of solar chimneys by varying the design parameters and examining their effects on the interior air temperature and speed.

Many different parameters affect the performance of the solar chimney. Solar irradiance is the most widely research parameter and also the most conclusive. Researchers find that air speed and temperature within the solar chimney increase with increasing solar irradiance. Within the interior, there is also a temperature drop and temperature lag. However, the value of solar irradiance is fairly constant during the hot tropical afternoon and the interior will already be thermally comfortable during low solar irradiance.

The inclination angle of the solar chimney is another widely research upon parameter, from fully horizontal to fully vertical. The greater the inclination angle, the higher the stack height, the lesser the flow resistance and the better the performance; however, the smaller the angle, the greater the exposure to solar irradiance and also the better the performance.

A chimney is device usually used to remove the hot flue gas or smoke to the atmosphere. It uses the stack effect to induce the movement. In buildings, the chimney also is used in natural ventilation, taking advantage of the differences of temperature between in-outside the building

A solar chimney is a kind chimney that uses the solar radiation to increase the temperature inside generating the stack effect to move the air. Usually it is used as a way to improve the natural ventilation for a building, solar collectors or solar drying technology. Also it can be used to generate electrical energy, but in this cases the size it considerably bigger, for example the solar tower built in Manzanares, Spain was 195 m high obtaining a maximum output power of 50 kW. This paper is focus only in the solar chimney as a way to improve the air speed in solar dryer.

There are significant number of papers are dealing with the investigation of the chimney effect in solar drying system as for example: Dawit et al. [2], Ekechukwu and Norton [3], Afriyie et al. [4], Elias [5] and Alex and Nyuk [6].

Ekechukwu and Norton [3] are represented the method to design and measure the performance of solar chimney used for natural-circulation solar energy dryers. The chimney that used consists of a 5.3 m high and 1.64 m diameter cylindrical polyethylene-clad vertical chamber, supported structurally by a steel framework and draped internally with a selectively absorbing surface. The performance of the chimney which was monitored extensively with and without the selective surface in place is also reported.

Alex and Nyuk [6] are tested the effect of the solar chimney's stack height, depth, width and inlet position on the interior performance as well as proposes an optimal tropical solar chimney design. The study shows that the output air temperature remains constant while the solar chimney's width is the most significant factor influencing output air speed. The solar chimney's inlet position has limited influence on the output air speed although regions near the solar chimney's inlet show an increase in air speed. To optimize solar chimney in the tropics, the recommendation is to first maximize its width as the interior's width, while allowing its stack height to be the building's height. Lastly, the solar chimney's depth is determined from the regression model by allocating the required interior air speed.

Because of the chimney effect concerning to the solar dryer a special attempt is carried out developing a low range air speed sensor for measuring natural ventilation during the solar drying process which can be used with a usual data logging system. Seres and Farkas [7] after choosing the working principle, they developed and constructed a one dimensional prototype of the sensor. Based on the measurements the optimal setting of the sensor was determined. Additionally, the set-up of a two dimensional sensor prototype is also presented, along with its measurement results.

Studying the flow conditions in a solar dryer, as the first step, the natural convection is to be studied due to the incoming solar radiation. In the applied model of Seres and Farkas [8] the collector was considered as a simple tube and in case of the low air speed of the natural convection the air flow is considered to be stationer.

The aim of this paper is to study the main parameters and characteristics for small air chimney that used with solar drying system.

2. Description of the solar dryer

On the basis of the explanations given before a small size dryer operated by solar energy seems to be realistic in many reasons. Such a dryer can cover the drying demand of a single farm. It is not planned to use as a raw corn drying or to replace the large-volume oil and gas heating dryers used from the mass grain production. Taking into account the high energy prices, environmental considerations and that the equipment has to operate in the fields far from the electrical grid the use of solar energy was planned for the artificial ventilation.

The solar dryer planned for such purposes has three main parts:

- a dryer (drying cabin) with different trashes for the different products. A trash holder with 4 trashes was developed for the surface drying when the product is too fine to flow the drying air through it. In this case the trash holder forces the air to flow above the product. Another trash holder with 7 trashes was developed for bulk drying, when to air flows through the product layers. The drying cabin has a size of about 0.8 m x 1 m x 0.65 m, and it has four legs with the height of 1 m.
- a PV module with the maximum power of 2x20 W and an electrical fan for artificial air circulation. The PV unit is installed in the front side of the dryer with changeable elevation angle, suitable to the different angle of the sunshine in the different periods of the year. Two switches allow the fan use at half or at whole power of the PV module.
- an air solar collector of about 1 m^2 attachable to the dryer for preheating the inlet air. The solar collector has the size of 2 m x 0.5 m x 0.2 m. It has a transparent cover on the top and thermal insulation at the bottom side. For the better energy reception a perforated plastic absorber plate was installed on the half height of the collector body.

Figure 1. The solar drying system

Because of the modular construction of the dryer it can be operated in different modes:

- Natural ventilation of ambient air. To assist this operating mode a chimney was planned to strengthen the air flow which is installed in the top of the drying cabin.
- Artificial ventilation of ambient air when the PV module is applied.
- Artificial ventilation of the drying air preheated by a solar air collector.
- The combination of the above modes can also be used.

The layout of the solar dryer studied in this paper is shown in Fig. 1 [9].

3. Modelling of the air flow

The chimney increases the amount of air flow, through the solar dryer by speeding up the flow of the exhaust air. Hence the effects of natural convection will be improved by adding a chimney in which exiting air is heated even more and enhance the buoyant flow of air. This will have a vital role to the overall design of solar dryers. Some study showed that the installation of three small fans and a photovoltaic cell is equivalent to the effect of a 12 m chimney. However, due to the air passing through the drying food item pick moisture and it possess a high relative humidity, its temperature may reach equal or lower than ambient (Figure 2). In such a case the generation of buoyancy force will be insignificant. To improve such conditions, heating the solar chimney above the ambient temperature would be advisable. The chimney should be designed so that the rate of heat losses within the chimney should be considered in determining the optimum height of the chimney so as not to exceed the height at which the chimney air cools to same temperature as ambient. The design will maintain mean chimney temperatures above ambient temperature.

Buoyancy is the force, along with the gravity, involved in the movement to upper positions of an object or fluid with less density than the fluid surrounding. In ideal gases when the temperature increases, the density decrease, thus a movement between the cold and warm zones appears. This movement is knowledge as Stack effect. The pressure difference of the stack effect is shown in the below equation:

$$\Delta P_{Stack} = g\ H\ \Delta\rho, \tag{1}$$

$$\Delta P_{Stack} = \rho\ g\ H\ (\Delta T / T_i). \tag{2}$$

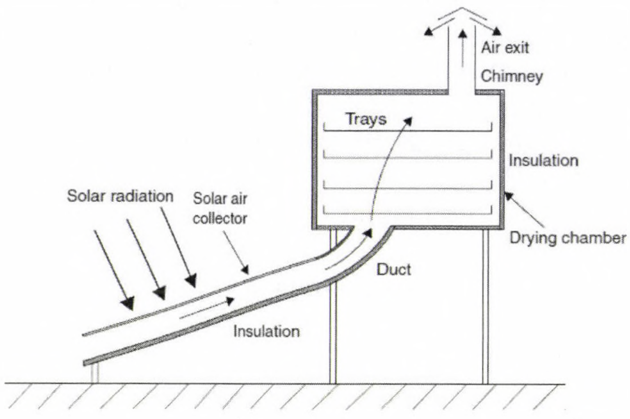

Figure 2. Schematic diagram of solar drying system

In the convectional solar dryer there are two basic conditions of air flow:

1. No flow condition: In this condition the air temperature and humidity inside the chimney and outside i.e. the ambient is similar. In this case there is no density difference hence there will be no flow through the chimney.
2. Flowing condition: In the flowing condition on the other hand, the mean temperature inside the chimney is relatively higher than the ambient air temperature. In this case, there exists a pressure head which creates an upward air flow. Therefore the relation among the buoyancy force that is the pressure drop that creates the air flow, the height, density difference of the ambient air and chimney is related as follows.

$$\Delta P_b = g\,H\,(\rho_a - \rho_{ch}). \qquad (3)$$

The pressure difference due to the buoyant pressure head in term of temperatures is given by:

$$\Delta P_b = g\,H\,\beta\,\rho\,(T_{ch} - T_a). \qquad (4)$$

Over the temperature range 25-90°C (within which natural-circulation solar-energy dryers would operate), the density of dry air is related to the temperature by the following empirical expression

$$\rho = 1.11363 - 0.00308\,T. \qquad (5)$$

By substituting equation (5) in (4), get:

$$\Delta P_b = 0.00308\,g\,H\,(T_{ch} - T_a). \qquad (6)$$

Within the chimney, pressure drops are due mainly to wall friction. Assuming turbulent flow (with a friction coefficient of 0.035), the pressure drop due to friction loss can be given as:

$$\Delta P_b = 0.035\,\dot{\rho}\,(v^2\,H / 2\,D), \qquad (7)$$

where $\dot{\rho}$ is the average density of fluid through the cylindrical duct (corresponding to the mean chimney air density for the case of the solar chimney). Combining equations (6) and (7),

$$0.035 \,.\, \dot{\rho}\,(v^2\,H / 2\,D) = \\ =0.00308\,g\,H\,(T_{ch} - T). \qquad (8)$$

Thus,

$$v = 0.453\,(D\,g\,\Delta Tch / \dot{\rho})^{1/2} \qquad (9)$$

as shown in above relation, the velocity is a function of temperature change across the chimney. It should be noted that the above expression is derived without taking into account the additional buoyancy arising from the increased humidity of the air stream. To include this would require assumptions to be made concerning the amount of moisture added to the air stream. The out let area or diameter of the chimney is designed as follows: Assuming no loss, the velocity of the air passing through the chimney.

$$m_a = (\pi/4)\,D^2\,v\,\rho_a. \qquad (10)$$

Then the mass of the air flowing through the cross-section of the chimney is given as follows:

$$m_a = A\,v\,\rho_a. \qquad (11)$$

During designing chimney of solar dryer, the most important emphasis should be on keeping the air temperature inside the chimney relatively higher than the ambient temperature. However; pressure drop due to the wall friction is commonly negligible. Therefore, an efficient solar chimney is designed to have mean inside temperature that is above the ambient air temperatures during operation.

4. Energy balance on the collector

In solar collectors the incident solar energy is partially absorbed in the glass and absorber surface, some amount of this energy is transferred to the fluid inside the collector and the remaining is lost to the environment. Thus an energy balance is developed basically that the useful energy gain is the difference between the absorbed solar energy and the thermal losses as shown in figure 2. Then it is solved by equating the total heat gained by the absorber to the total heat loss of the solar collector. Then, it is expressed as follows.

$$I A_c = Q_u + Q_{cond} + Q_{conv} + Q_{rad} + Q_{ref}. \quad (12)$$

To audit all the energy balance the following heat components must be considered. The incident solar radiation (I), top heat loss coefficient, coefficient of convective heat transfer between cover and air, coefficient of convective heat transfer between plate and air (Q_{conv}),coefficient of radiation heat transfer between plate and cover (Q_{rad}.) , bottom heat loss coefficient, ambient temperature, collector air temperature and mean plate temperature.

The flat plate solar collector with size 2 m x 0.5 m x 0.2 m has been tested. The solar collector connected to the dryer chamber to heat air flow stream that will enter the chamber. It has a transparent glass cover fixed on the top edges of the solar collector box and good thermal insulation at the bottom base and sides of the metal box. For the better energy collection a black absorber plate was put on the half height of the collector body box. The solar collector in this work is oriented facing south line and tilted at 45o to the horizontal according to the solar chart for Budapest region. To get more absorption of solar radiation and radiation reflection reduction, absorber plate painted with matt black colour.

5. Efficiency of solar dryers

Commonly the efficiency of solar dryers is evaluated either based on the thermal performance or the drying rates (system drying efficiency) of the products. The thermal analysis of a solar collector is quite complex. However, according to the ASHRAE 93-77 standard, the thermal performance of the solar collector is determined in part by obtaining values of instantaneous efficiency for a combination of values of incident radiation, ambient temperature, and inlet fluid temperature. This requires experimental measuring the rate of incident solar radiation on to the solar collector as well as the rate of energy addition to the transfer fluid as it passes through the collector, all under steady state or quasi-steady state conditions. Therefore the instantaneous efficiency of a collector is expressed as follows:

ηc = useful energy collected / incident solar energy.

When the useful energy is expressed in terms of mass flow rate and the change in temperature the collector efficiency is stated as follows.

$$\eta_c = m_a C_p (T_o - T_i) / I A_c. \quad (13)$$

The other important measure for efficiency of solar dryers is the drying rate or the system drying efficiency. The system drying efficiency is defined as the ratio of the energy required to evaporate the moisture from the product to the heat supplied by the drier.

$$\eta_d = m_w h_{fg} / I A_c. \quad (14)$$

Balance equation for the evaporation of water from the products inside the dryer system is

$$W L = m_a c_p (T_1 - T_2). \quad (15)$$

From the above relations, the rate of water evaporated from the products inside the drying chamber related with air velocity inside the drying chamber. The objective of chimney is to increase the velocity of air naturally then will increase the efficiency of drying. From this point, the chimney gets the importance. So, getting good air speed for which product depends on chimney design.

6. Conclusion

The rate of water evaporated from the products inside the drying chamber related with air stream velocity inside the drying chamber. The objective of chimney is to increase the velocity of air naturally then will increase the efficiency of drying. From this point, the chimney gets the importance. So, getting good air speed for which product depends on chimney design (air flow area). But the increasing of air speed more than limits, will give bad side effects for some products.

In the flowing condition on the other hand, the mean temperature inside the chimney is relatively higher than the ambient air temperature. In this case, there exists a pressure head which creates an upward air flow. The velocity is a function of temperature change across the chimney. It should be noted that the above expression is derived without taking into account the additional buoyancy arising from the increased humidity of the air stream. To include this would require assumptions to be made concerning the amount of moisture added to the air stream.

Nomenclature

A	absorber area of solar collector	m^2
C_p	specific heat at constant pressure	kJ/kg.K
D	duct diameter	m
g	acceleration due to gravity	m/s^2
H	height	m
h_{fg}	enthalpy	kJ/kg
I	incident solar radiation	W/m^2
L	latent heat of vaporization of water	kJ/kg
m	mass flow rate	kg/s
P	pressure	Pa

Q	heat transfer rate	W
T	temperature	K
v	velocity	m/s
W	water mass evaporated from product	kg/s

Greek letters

β	bulk coefficient of expansion of air	1/K
Δ	change	----
η	efficiency	----
ρ	density	kg/m^3

Subscripts

a	air
b	buoyancy
c	collector
ch	chimney
d	dryer
i	inlet
1	input
2	output

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Faculty of Mechanical Engineering

STUDY OF INLET LIGHT SPECTRUM'S EFFECT ON PLANTS GROWTH - THE LIGHT TRANSMITTANCE DECREASED WITH INCREASING GLASS THICKNESSES

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Abstract

The aim of this study was to measure some effects of light spectrum on the growth of greenhouse plants to be able to reduce overheat in hot summer periods. To reduce the light's impact two series of experiments were carried out. In the firs tests various double glass panels were involved. Light spectrometer was used to measure the transmitted light spectrum of the panels in empty and in different colour water-filled state. The red colour fluid was the one which transmitted the spectrum range appropriate for the photosynthesis of plants the best, it also filtered the IR range most. In the second test series three groups of strawberry seedlings were used to test the effect of filtered light transmittance. The plants below the red panel were taller, their leaf number was larger, and no sunburn was found compared to those under plain water and plain air.

Keywords

light spectrum, greenhouse, photosynthesis

1. Introduction

Light is one of the most important climatic factors for the photosynthetic activities of the plants. Crop growth is directly related to the available solar radiation [1]. Spectrally analyzing the absorption recesses of the various plant species are in the same places for each plant species (a water content manifestation), given the differences in the number of DN-levels [2].

Greenhouses create optimal climate conditions for crop growth and protect crops from outside pests. At the same time greenhouse production increases water use efficiency and makes integrated production and protection (IPP) possible [3].

The abiotic stress reduces the growth of plants, the intensity of the photosynthesis. Such stress is the high-intensity light and excessive heat. These conditions occur in greenhouses not only during the high summer heat waves. The short-wave solar radiation (300 to 2500 nm wavelength) enters through the transparent roofing material in the greenhouse and is absorbed by plants, installation and construction parts. This heats the air temperature of the greenhouse. The technical requirement for greenhouses is to reach the optimum light transmission and thermal insulation for the high plant productivity by the use of appropriate covering [4]. With theoretical advances an understanding of light transmission processes an improved evaluation and design of greenhouses can be achieved [5], [6].

The greenhouse production is most typical in the vegetable production. The production is continuous, running also in summer. The operating costs in summer give the shading and the ventilation . The aim of this study was to measure the spectrum of transmitted light through a variation of glass covers to improve light and temperature conditions for plants grown in greenhouse, and so to reduce the costs with simple technical methods [7].

2. Materials and Methods

To reduce the impact of light two series of experiments were carried out. In the first one different double glass panels were tested to see their light transmittance. All the panels were 20x20 cm large. Their thickness was different, due to the different glass sheets thicknesses (3, 4 and 6 mm respectively) and inner distances between the glass sheets (8, 12 and 20 mm respectively). This way 9 different panel variation were constructed. The tests were carried out with empty, plain water filled and colour water filled panels. The transmitted light spectrums through the panels were measured by an Ocean Optics, USB 2000 spectrometer. As light source a Landlite (GU10, 230V, 50W) halogen electric lamp was used. Its spectral image compared with the sun's spectrum is shown on Figure 1. There is a considerable difference between them, but for the comparison of different panel arrangements it seemed to be an acceptable solution. During the tests red, yellow, green and blue coloured water was used. For colouring the water Max Color food colours were used, made by the Hungarian company Szilas Aroma Ltd.

The testing rig was composed of the lamp, the panel and the spectrometer arranged in a black box. It enabled the easy change of panels (Figure 2).

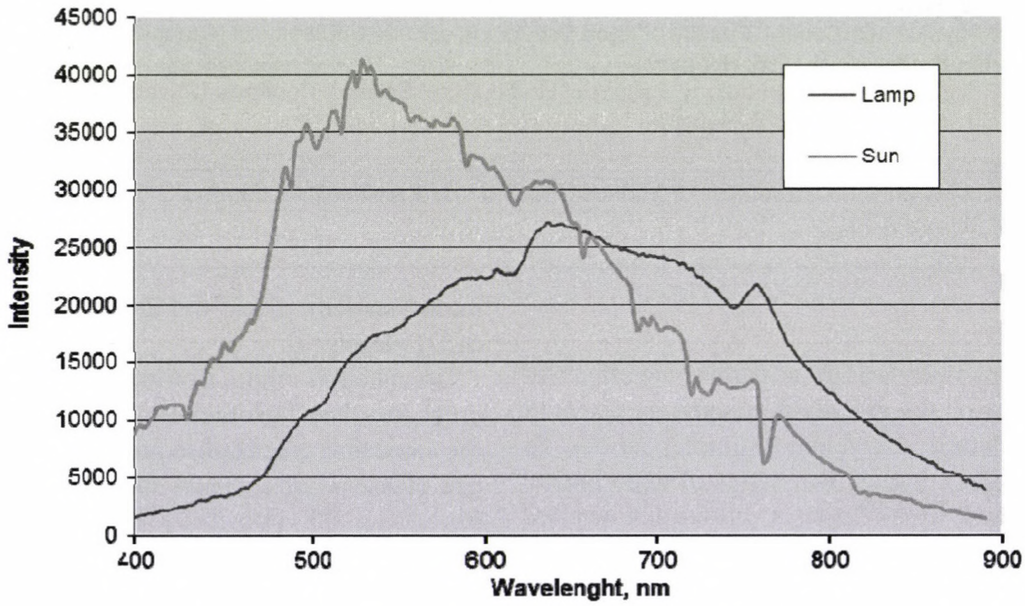

Figure 1. The light spectrum of the Landlite halogen lamp and the Sun

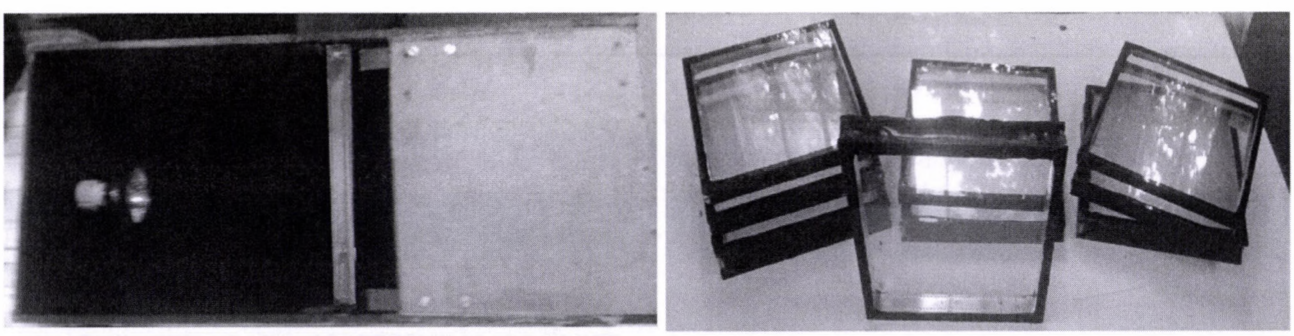

Figure 2. The arrangement of transmittance tests of panels

In the second test series three groups of strawberry seedlings were used to test the effect of filtered light transmittance. The test arrangement included two double glassed panels of 80 cmx80 cm size, fixed on a frame at 50 cm above ground in horizontal position, next to each other. In both cases the top glass was 3 mm, the bottom one 6 mm tick to withstand the water pressure. One panel was filled with clear water, the other one with pale red water. One group of strawberry was placed below the pale red water filled panel, the other group below the clear one (Figure 3). The third group was regarded as control: it was not sheltered.

Figure 3. Test arrangement for comparing plant growing

Table 1. Temperatures of surfaces and of air

	Temperatures (°C)				
Date	plants	roof	panel with water	panel with red water	ambient air
2015.08.07	32,8	57,9	34,4	37,4	35,8
2015.08.10	34,2	58,2	34,5	37,6	36,5
2015.08.17	24,1	28	24,6	25,3	28,5

The seedlings were the same kind, the same generation, had the same physiological capabilities. The measurements were carried in August 2015. The temperature under the panels and in the environment was regularly measured by a Fluke thermal camera. Some characteristic values are shown in Table 1.

Gas exchange measurements were also carried out on the leaves of the plants using an infrared gas analyser (LCI, ADC Bioscientific Ltd., Hoddesdon, UK). CO_2 assimilation, transpiration rate, leave temperature, photosynthetic activity and PAR (Photosynthetic Active Radiation) spectrum were measured.

3. Results and Discussion

The results for light absorptivity of empty glass panels are shown in Figure 4. The data in the left figure indicate the effect of glass thickness, the figure on the right show how the size of the spacer influences the absorptivity.

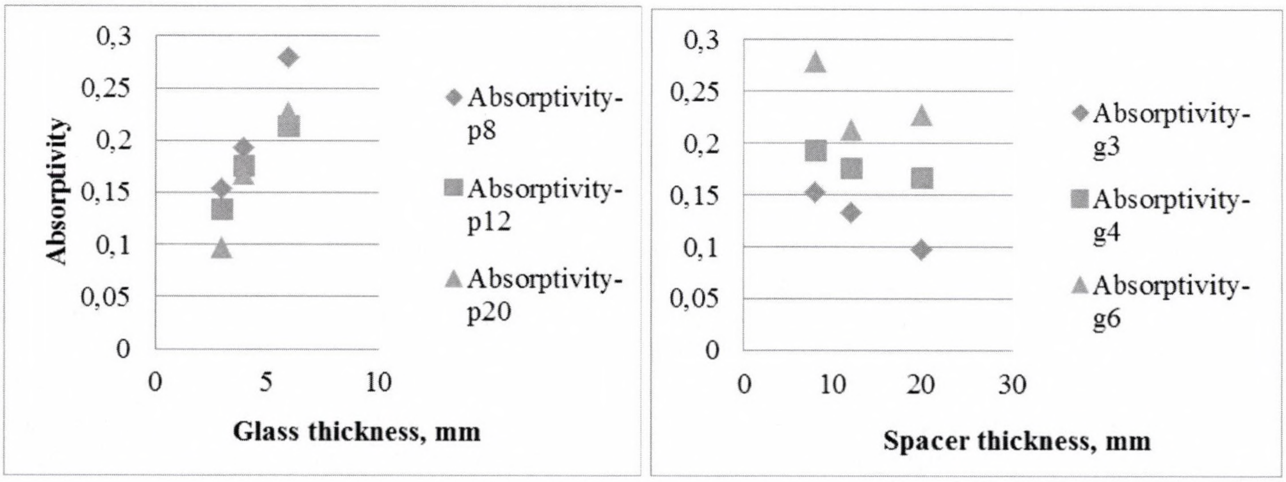

Figure 4. Absorptivity of the of empty glass panels

From the measured data it was clear, that the light transmittance decreased with the increase of glass thickness, but with the increase of spacer the transmitted light intensity also increases.

When the panels were filled with water, in the thermal range (in the IR range) a reduction appeared (Figure 5). According to other tests with growing spacer the decreasing transmittance trend appeared. Thicker layer of water reduced more the light intensity.

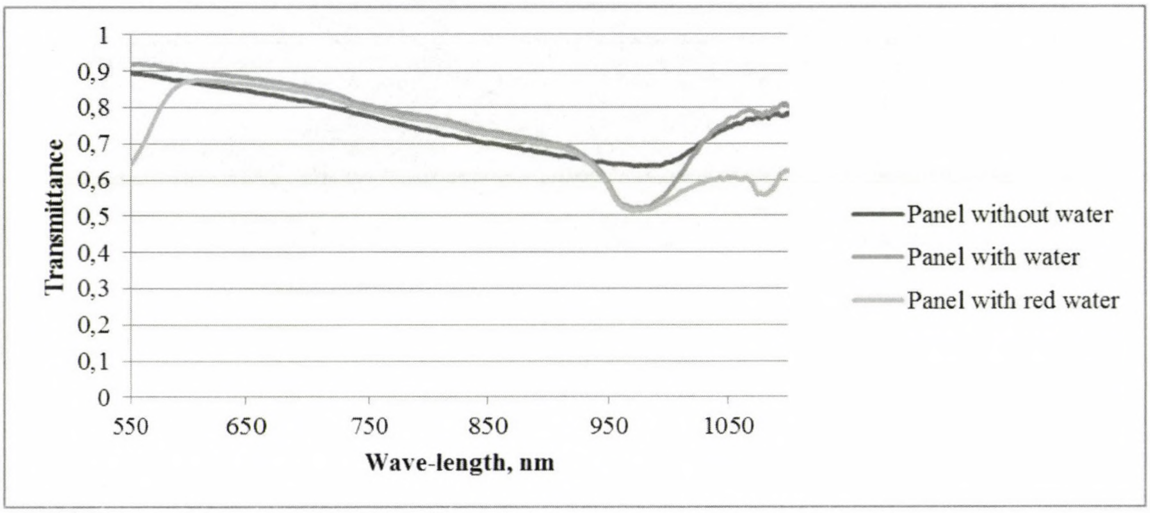

Figure 5. Transmittance of glass panel (without water, with water, with red water)

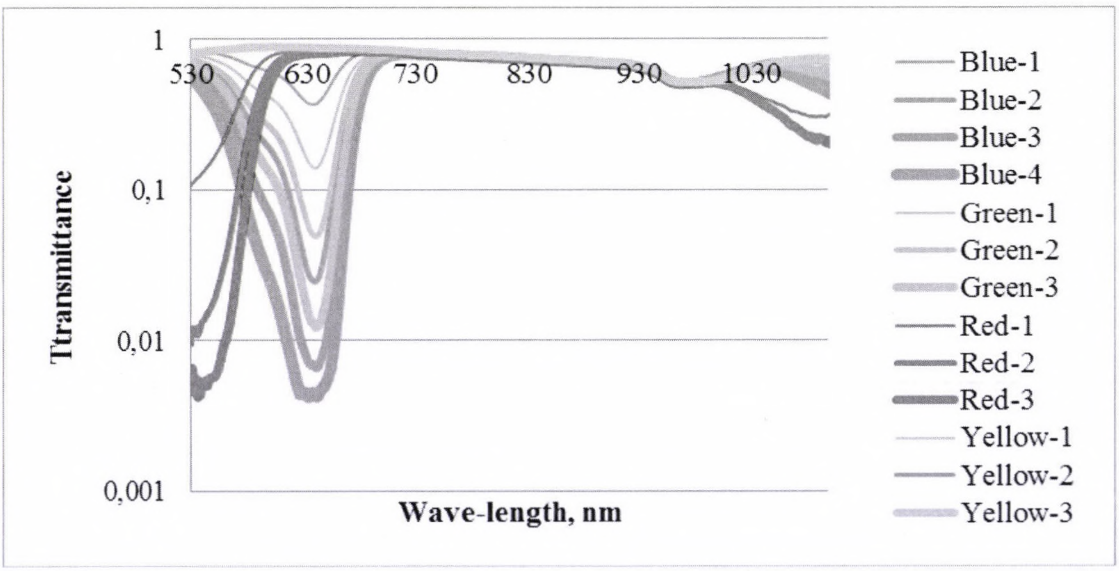

Figure 6. Transmittance of colored water panels

The transmittance test results of yellow, blue, red and green coloured water are shown on Figure 6. Compared with clear water the yellow water gave hardly any difference. A smaller reduction in higher wave-lengths was found in case of the blue and green fluid, but in the active region of photosynthesis the transmittance reduced significantly, which does not meet our expectations. Using the red colour fluid the spectrum range needed for the photosynthesis of plants was transmitted, while the IR range was filtered mostly. On Figure 6 the different thicknesses of colour lines belong to the different concentrations of colours in water.

The results of the gas exchange measurements are presented in Figures 7 and 8. The leaves of 8 plants under the clear water panel and 9 plants under the red panel were measured with the infrared gas analyser.

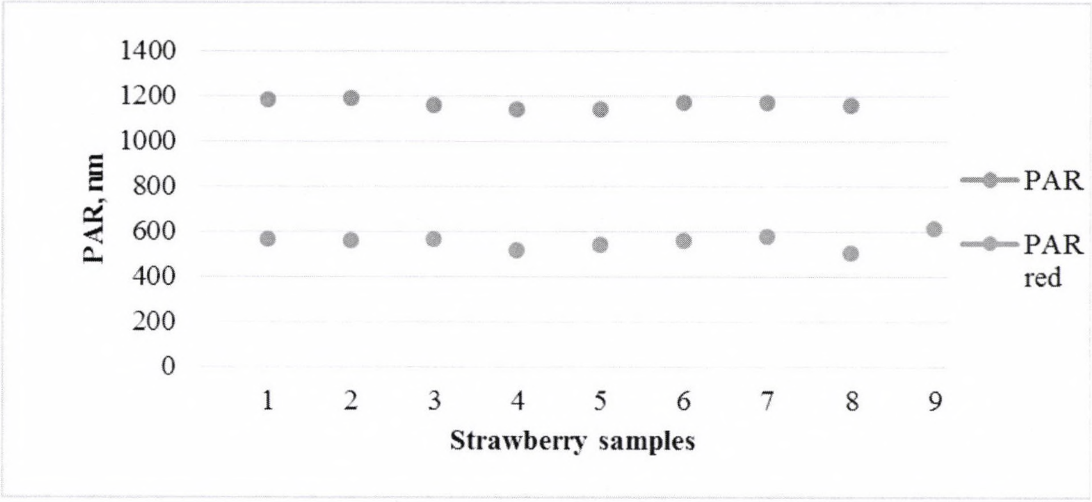

Figure 7. PAR values of strawberry samples under the panels

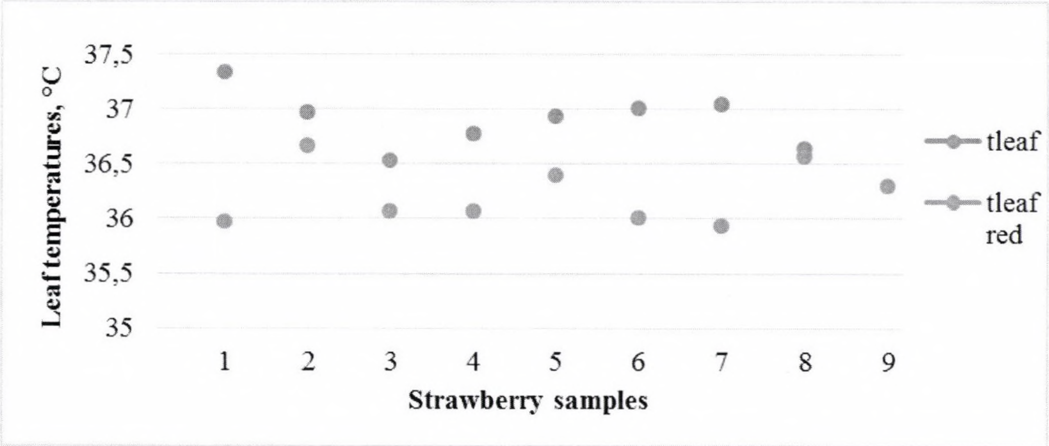

Figure 8. Leaf temperatures of strawberry samples in °C

Under the red panels, the PAR values was only half of that measured under the "clear" panel. Under the red panel the leaf temperatures were always lower by 0,5-1 °C compared with the clear water filled panel. The red panel protected better the plants from light and heat stress. The active transpiration values (Figure 9) were also higher (or the same) as under the "clear" panels.

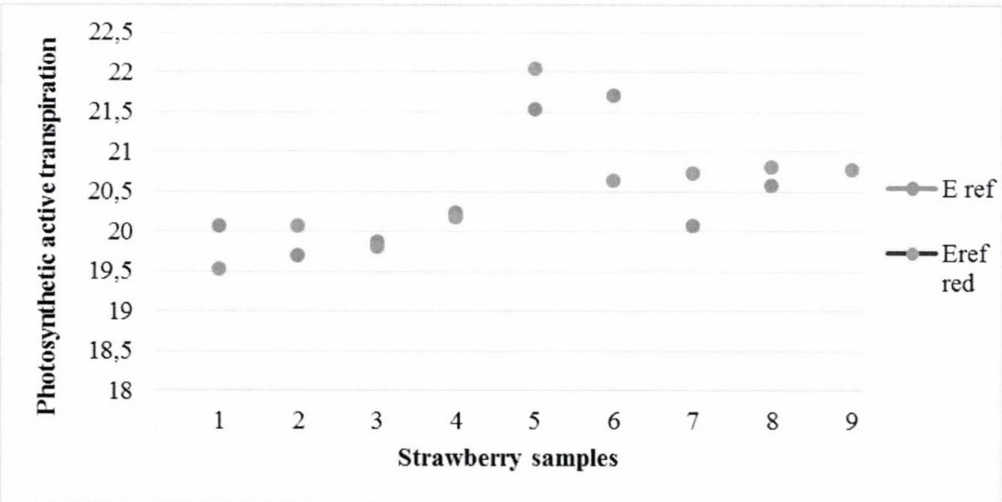

Figure 9. Photosynthetic active transpiration values of strawberry samples

Visual examination at the end of August has shown, that all control plants (not under the panels) died, almost all plants under the plain water panel was smaller and signed of a slight sunburn on the leaves, especially along the edges, the inside of the stock has remained completely intact. The plants below the red panel were taller, the leaf number was larger, and no sunburn at all was found. The number of plants has grown, the typical vegetative reproduction of strawberries started. In addition, several fruits have been on the seedlings.

4. Conclusion

From the test results it is clear, that the light transmittance decreased with increasing glass thicknesses, but the transmitted light intensity increased with the higher inner distance values. Compared to other coloured water only in the red fluid transmitted the spectrum range needed for the photosynthesis of plants, while the IR range was filtered strongly. This statement was proven by a simple fruit growing test: strawberries grown under pale red shelter were much less impacted by high ambient temperature, while plants under no colour shelter suffered from sunburn, and control plants without any shelter died off. On the base of these first results further research work is planned to clarify more exactly the effect of the red colour fluid filled double glass cover.

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ANALYSIS OF ONSET AND CESSATION OF RAINFALL IN SOUTHWEST NIGERIA: FOOD SECURITY IMPACT OF OF VARIABILITY IN THE LENGTH OF GROWING SEASON

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Abstract

The analysis of onset and cessation of rainfall for selected locations in South west Nigeria was carried out using daily meteorological data for five synoptic stations (Ikeja, Abeokuta, Ondo, Ibadan and Osogbo) in the region. The FAO Rainfall–Evapotranspiration model was used to elucidate the length of growing season and the impact of climate change on climatic variables and agricultural productivity. Results revealed that the wet season lasts from March to November within the period (2001–2014). The onset and cessation dates varied across the five locations that were considered; Ibadan and Ondo had an early onset of rain while Ondo and Oshogbo had a late cessation, while other stations considered had similar onset and cessation days. The length of the growing season range from 219 – 228 days within the region, this suggests the types of crops that can be supported by the rain fed cropping system predominantly practiced in the region and the number of growing cycles that can be accommodated. The study also revealed that weekly analysis of data gave better result than monthly analysis, while daily analysis did not lead to any useful results. The results are of inestimable value for the planning, organization and execution of agricultural activities in the region and in areas of similar climate around the world.

Keywords

Rain–fed farming, rainfall Onset, cessation, growing season, Nigeria

1. Introduction

Crop production in Nigeria is predominantly rainfed especially in the south west region where irrigation development is very low. The length of growing season had always been uncertain due to high variability of onset and cessation of the wet season [1]. In some years the rains start early, while in other years it arrives late. This yearly variation makes the planning of selection and sowing of crop types and varieties difficult.

The seasonal and inter annual variability of the weather is caused by the El Niño-Southern Oscillation (ENSO) as a result of the shifts in the sea surface temperatures (SST) in the Eastern and Western Equatorial Pacific, coupled with shifts in barometric pressure gradients and wind patterns in the tropical Pacific (the Southern Oscillation); the ENSO phenominon influences rainfall which in turn impacts rainfed crop production system.

Generally, crop yields may suffer significantly with either a late onset or an early cessation of the growing season as well as with a high frequency of dry spells within the growing season. The ability to estimate effectively the actual start of the season therefore becomes vital. In order to plan rainfed agriculture, dependable probability levels of onset date and cessation date of rainfall and length of growing season are important. Climate change has affected rainfall distribution across Sub Saharan Africa (SSA), as there is either less or more rainfall than the farmers have been accustomed to [2]. To make matters worse, the amount of rainfall for a given period can no longer be predicted accurately. Consequently, farmers are bound to suffer heavy losses due to either inadequate or excessive rainfall. In the case of inadequate rainfall, a well-planned irrigation intervention could be used as an alternative; unfortunately, excessive rainfall is difficult to remedy and it is accompanied by environmental degradation and devastation [3].

In addition, torrential rains that cause flooding does not only destroy crops, livestock and other land resources, they also destroy homes and valuable infrastructure especially roads and bridges. This on the long run hinders the farming populations from markets, which their produce could be sold out to, and also blots access to education and healthcare facilities. The resulting effect is that agricultural growth and farmers' living standards would be seriously compromised. [4] reported that extreme and unusual weather events, resulting in loss of life and property, and disruption of socio-economic activities, are being experienced all over the world. The increasing frequency and intensity of these events constitute a major challenge to socio-economic development, particularly in developing countries. Nigeria is not exempted from this global phenomenon, because wet season is characterized by thunderstorms, strong winds and turbulence at the onset and cessation phases of any wet season therefore timely weather and climate information are vital tools for planning.

In Nigeria, rain falls in different months of the year at different places, as the rain belt appears to follow the relative northward and southward movements of the sun [5]. In this situation of a marked seasonal rainfall regime, variability of the onset and cessation of rain is highly significant, and its estimation and prediction are necessary [6]. A delay of 1 or 2 weeks in the onset is sufficient to destroy the hopes of a normal harvest while a false start of planting, encouraged by a false start of rainfall may be followed by prolonged dry spells whose duration of 2 weeks or more may be critical to plant germination and/or growth [7].

Several approaches have been developed over the years for analysing the onset, cessation and the length of growing season; according to [8], the techniques used can be broadly grouped into two, namely the direct and indirect methods. The direct methods define growing season using rainfall threshold criteria [9][1][10]. The indirect methods involves the use of rainfall-evapotranspiration model [11], upper wind data [12] and equivalent potential temperature [13]. [14] also proposed a combination of rainfall amount and Normalised Difference Vegetation Index (NDVI) which proved to be effective in south west Nigeria. The ease of application of the techniques differ in terms of data requirement and depth of analysis; [2] reports that the rainfall-evapotranspiration model pioneered by [3] is by far the easiest to apply.

The approach defined the onset of the rainy season as the date after which mean rainfall amount over any given period of time interval is consistently greater than half of the mean ET over the same period under consideration. The agronomic importance here is that more than 50% of field moisture lost through evapotranspiration can be replenished by rainfall for successful crop growth and development.

This study aims at analysing recent onset and cessation of rainfall in some important agrarian centres in south west Nigeria using the rainfall – evapotranspiration model approach and to determine specific length of growing season for the centres.

2. Materials and Methods

The study area is south west Nigeria, which consist of Lagos, Oyo, Osun, Ondo and Ekiti states. The area lies between lat. 60 32' N – lat. 80 57' N and long. 20 31' E – long. 50 48' N [15], with a total land area of 77, 818 km2. The study area is bounded in the east by Edo and Delta states, in the north by Kwara and Kogi states, in the west by the republic of Benin and in the south by the gulf of Guinea. The climate of southwest Nigeria is tropical in nature and it is characterized by wet and dry seasons.

The mean temperature ranges between 19 °C and 30 °C, while the annual rainfall ranges between 924 mm and 2016 mm; the wet season is associated with the southwest monsoon wind from the Atlantic Ocean while the dry season is associated with the northeast trade wind from the Sahara desert. Figure 1 shows the map of the southwest states of Nigeria.

The meteorological data required for the analysis were sourced from the Nigerian Meteorological Agency (NIMET). A total five synoptic stations in the south west region of Nigeria were selected, namely: Ibadan, Lagos, Abeokuta, Ondo and Osogbo for year 2001 – 2014. Table 1 shows the characteristics of the stations used and the available data for the study. The data set was made up of time series of daily rainfall, daily minimum and maximum temperatures, daily relative humidity and daily solar radiation. The selected stations had continuous records for the years considered (2001 – 2014). Quality control checks were carried out for homogeneity of data set and outliers were removed, missing values were estimated from the mean values obtained from three neighbouring stations. Daily evapotranspiration data were synthesized using the Blaney–criddle model according to [16]:

$$ET_o = P(0.46T + 8.13) \quad (1)$$

Where, ET_0 is known as potential or reference evapotranspiration

P is known as mean daily percentage of annual daytime hours in (%)

T is known as mean air temperature in (°C)

The FAO rainfall–evapotranspiration model [3] was used to analyse onset and cessation of rainfall. The model presented in Eq. (1) defines the onset of rain as the date after which mean rainfall amount over any given period of time interval is consistently greater than half of the mean evapotranspiration over the same period under consideration. It also defines the growing season as any week in the initial period of a wet season within which rainfall amounts totals to at least 25 mm or any 10 day period in the initial period of the wet season with a total amount of at least 30mm and followed by the continuity of rain for good emergence and vegetative of crops. The analysis was carried out using monthly, weekly and daily time step to determine the most appropriate approach.

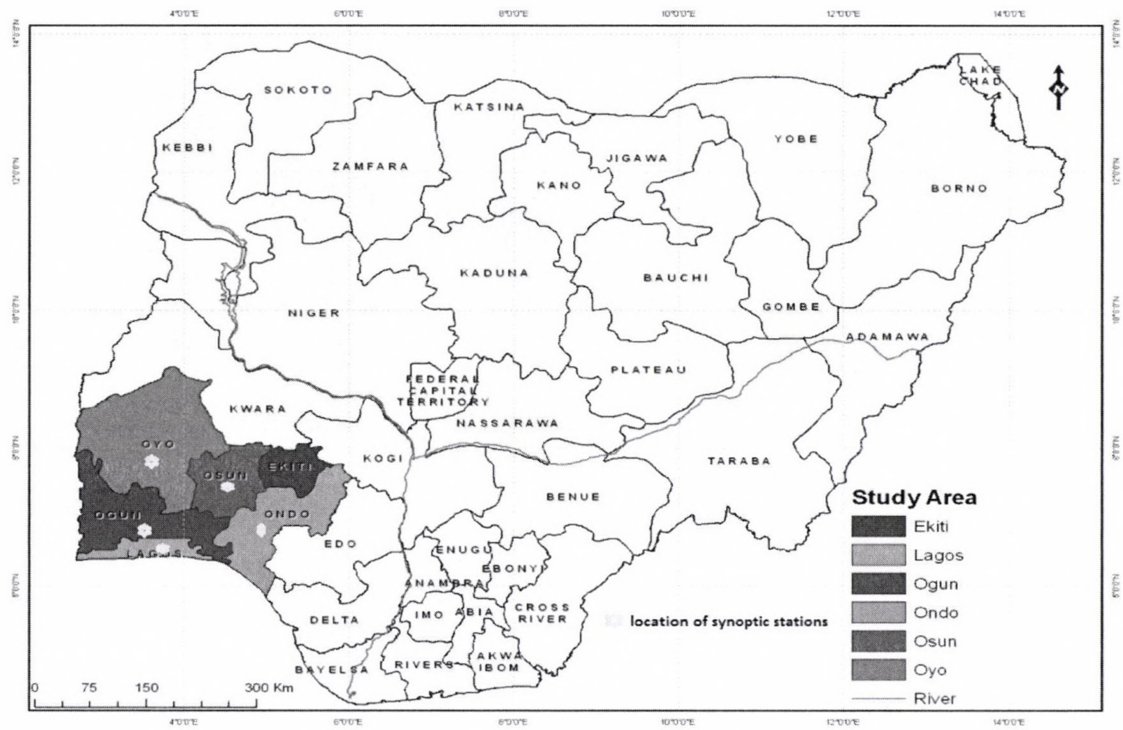

Figure 1. Study locations in Nigeria

Table 1. Characteristics of selected synoptic stations [4]

Station name	Station No.	Latitude	Longitude	Elevation a.m.s.l. (m)	Record (years)	Available Data
Lagos	65203	6^0 27' N	3^0 24' E	14	10	R, T_{min}, T_{max}, RH,
Ondo	65222	7^0 6' N	4^0 50' E	287.3	10	R, T_{min}, T_{max}, RH, SR
Ibadan	65208	7^0 26' N	3^0 54' E	229.2	10	R, T_{min}, T_{max}, RH, SR
Abeokuta	65213	7^0 10' N	3^0 20' E	104	10	R, T_{min}, T_{max}, RH, SR
Oshogbo	65215	7^0 47' N	4^0 29' E	302	10	R, T_{min}, T_{max}, RH,

R indicates rainfall, T_{min} is minimum temp., T_{max} is maximum temp., RH is relative humidity and SR is solar radiation

3. Result and discussions

Characteristics of rainfall in south west Nigeria

Figures 2 and 3 shows the annual trend and distribution of rainfall at the five stations, close observation revealed that rainfall has a marked variability within the period. Annual total rainfall ranged between 849 mm (Abeokuta) to 2,207 mm (Lagos), further analysis show that year 2001 presented the least rainfall while 2010 has the highest rainfall. The implication of this is that year 2010 presented an opportunity for increased food production and at the same time has the highest risk for flooding and environmental degradation. The fact that Abeokuta has the least rainfall in the region is a surprise despite its proximity to the station with the highest rainfall (Lagos) and its low elevation (130 m above mean sea level). The reason for this is largely unknown but it is suspected that this might be due to the evolving derived savannah vegetation status of the area; however, this claim needs to be investigated. Local experience has shown that rainfall in Abeokuta and environ has been largely orographic in nature owing to the numerous granitic rock outcrops wide spread in the town. This point to the fact that rainfall will be highly variable, erratic and unevenly distributed.

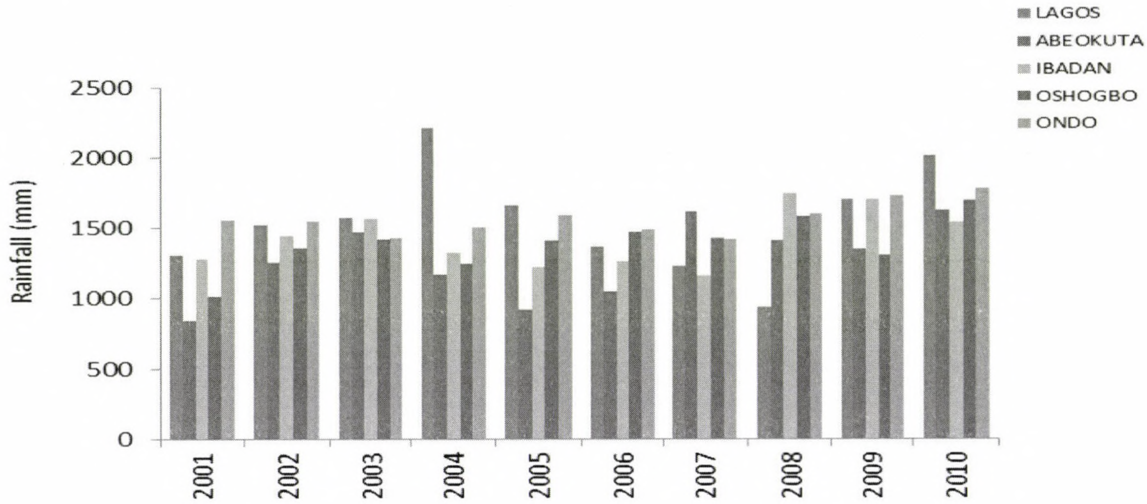

Figure 2. Annual totals of Rainfall in the Southwest

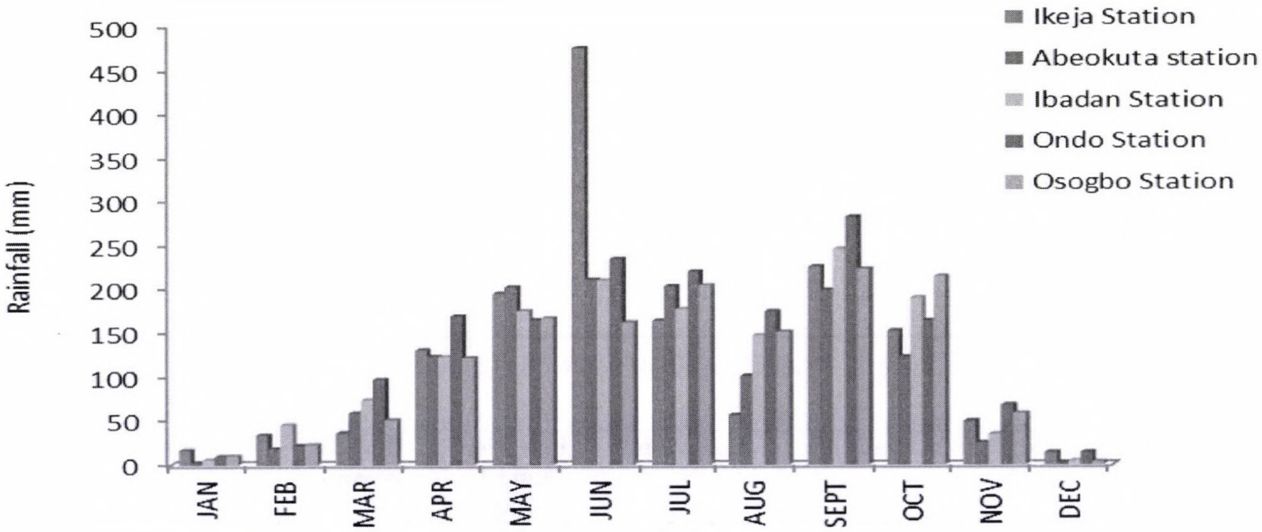

Figure 3. Monthly Rainfall distribution in southwest Nigeria (2001-2014)

The rainfall regime in the region within the decade was found to still follow the traditional double maxima characteristics, it should however be noted that the marked short dry spell usually experienced in the month of August is fast disappearing owing to climate change, this can easily be seen in figure 3. The analysis of rainfall occurrence in the month of August shows that Lagos has the lowest rainfall values followed by Abeokuta, other stations show evidence of appreciate rainfall values revealing that the August break is already cancelling out in the region. The month of June experienced more rainfall than any other month at Lagos station with a maximum rainfall of 475 mm. In the month of January, Abeokuta has the lowest rainfall of all the stations followed by Ibadan, Ondo, Osogbo and Lagos respectively. The second rainfall maxima occurred in the month of September across the region. It was also noticed that the amount of rainfall in November and December dropped sharply due to the dry season.

Onset and Cessation of Rainfall

Daily analysis of the rainfall data did not produce any significant result of the dates of onset and cessation of rainfall, showing that precise identification of the point where rainfall amount will be greater than half of the mean evapotranspiration is not feasible; this suggest that applying daily rainfall and evaporation data for the FAO model is impracticable. Monthly data analyses on the other hand produced useful results but do not lend itself to accurate estimation of onset and cessation dates as can be seen in Figure 4; when weekly analysis was implemented, the results were very satisfactory as the days when onset and cessation of rainfall occured were clearly identified. The onset and cessation dates varied across the five locations that were considered; Ibadan and Ondo had an early onset while Ondo and Oshogbo had a late cessation of rain. Other stations had similar onsets and cessation days as shown in Table 2, it is however surprising that Lagos being the closest to the Atlantic ocean and the most southern location had its onset date falling on April 2 behind Ibadan and Ondo.

The fact that Lagos received the largest amount of rainfall in the decade makes this discovery a subject of further research.

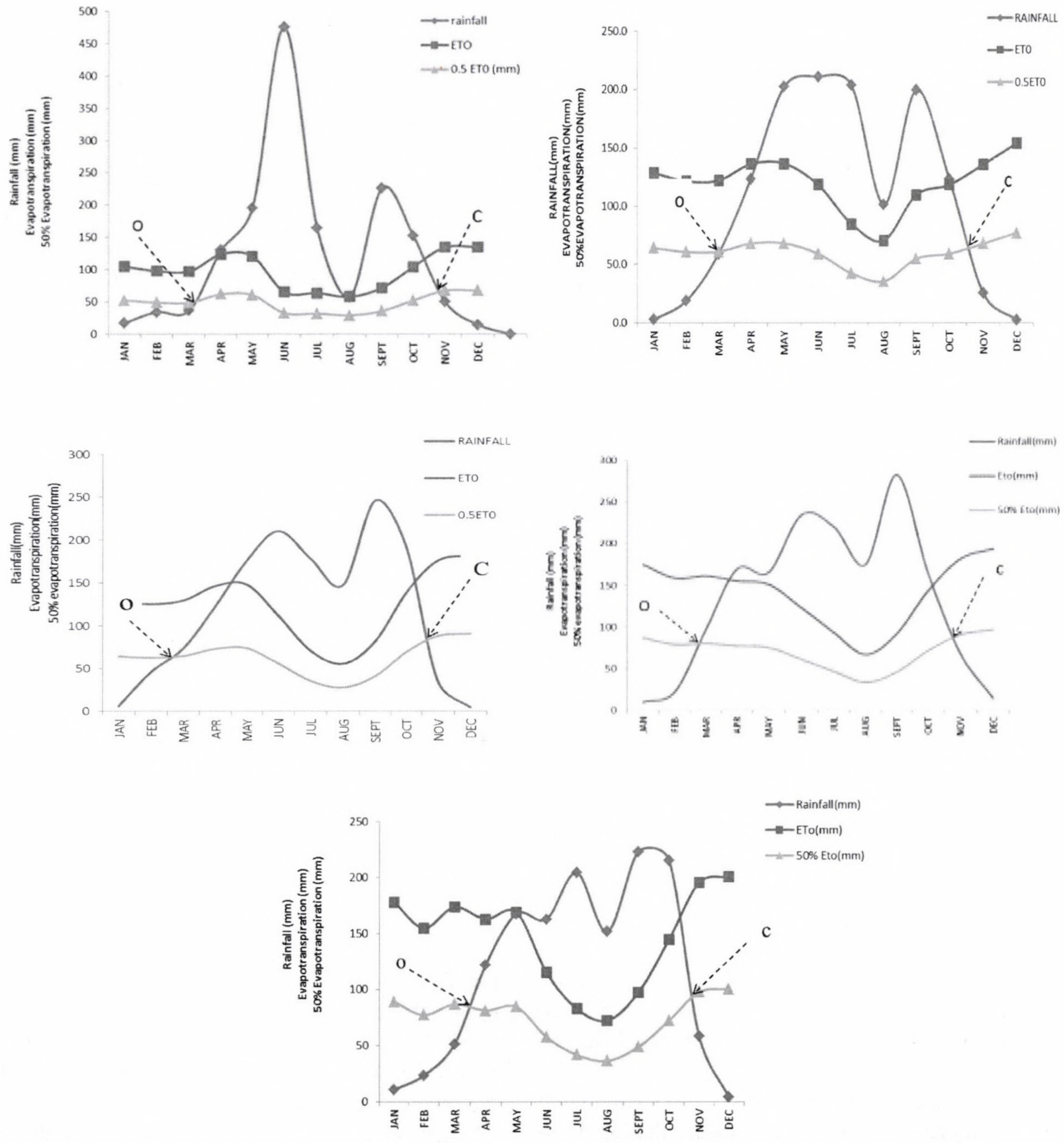

Figure 4: Onset and cessation of rainfall at selected stations in south west Nigeria

The length of the growing season was found to range between 219 – 228 days within the period of study, indicating the types of crops that could be sown and the number of cycles of such crops that can be accommodated in the season.

Food security impact of variability in the length of growing season

Sub Saharan Africa have been reported to be one of the most susceptible and vulnerable region to variability in the length of growing season; the sub region have large populations of the poor with very low access to basic resources such as irrigation water and productive land [17]. Projections show that by 2020, between 75 and 250 million people in Africa will be exposed to increased water stress and in some countries, yields from rainfed agriculture could be reduced by 50 percent.

The information above is stagerring and require pragmatic efforts to address the expected shortfall in food production. [18] reports that crop yield is more sensitive to the precipitation than temperature, hence the need to give adequate attention to the length of growing season in all affected areas; the observed variability in the length of the growing season cannot be modified in any way but can be adapted to by the practice of climate smart production systems and strategies. One of such strategies lies in the choice of crops to plant; because of the reducing length of growing season, certain crops may no longer be supported by rainfed production, necessitating a change in the cropping calendar.

For example, for a hypothetical choice of a crop like maize which is commonly grown in sub saharan Africa and with days to maturity ranging from 80 – 90 days depending on variety; the observed length of the growing season in southwest nigeria will only be able to accommodate two production cycles of maize conveniently unlike what obtains in the past when three cycles were possible. Obviously, the climate has changed and its effects on our agricultural production systems are very evident and will have its toll on food security.

Another strategy is to enhance irrigation development; this will provide supplemental water to crops and increase the growing season. At present, irrigation practice is not well developed in the study area in sharp contrast with the northern parts of Nigeria, despite the fact that the area is water rich. State governments in the region needs to harness the water resources of the region and invest in irrigation so as to engage the army of jobless youths in the region and enhance food security.

Table 2. Summary of Rainfall onset and cessation dates in southwest Nigeria (2001 – 2014)

Station Name	Location	Onset Date	cessation Date	Length of growing Season (days)
Lagos	Lat. 6^0 27' N, Long. 3^0 24' E	April 2	November 7	219
Abeokuta	Lat. 7^0 10' N, Long. 3^0 20' E	April 1	November 8	222
Ibadan	Lat. 7^0 26' N, Long. 3^0 54' E	March 30	November 9	224
Ondo	Lat. 7^0 6' N, Long. 4^0 50' E	March 30	November 13	228
Osogbo	Lat. 7^0 47' N, Long. 4^0 29' E	April 3	November 10	221

In low-rainfall areas where moisture stress is expected to remain a primary constraint on plant growth, [19] suggested planting faster-maturing crop varieties that avoid drought or heat stress during sensitive stages of plant growth, such as flowering or grain filling.

Developing faster-maturing varieties of crops for areas with short and highly variable rainy seasons should be the goal of crop breeding programs, and such a strategy would seem promising anywhere climate change is expected to shorten the length of growing seasons.

It is equally advisable to promote crop switching by farmers in order to plant crop varieties that are more tolerant to the new climate regime, this might be a little difficult but must be promoted. Farmers in Sub Saharan Africa do not easily yield to changing old, unprofitable ways for the new; much persuasion need to be done through extension services and incentives.

4. Conclusion

The onset and cessation of rainfall in the South western region of Nigeria was evaluated using the FAO rainfall – evapotranspiration model. Results revealed that the onset dates range from March 30th – April 3rd, while cessation of rain occurs between November 7th – 13th across the region. The length of the growing season was found to range from 219 – 228 days for the period of study, this suggest the types of crops can be supported by a rain fed system and the number of growing cycles that can be accommodated in the region. The implication of these is that the climate in the region has actually changed as projected by IPCC; south western part of Nigeria is located within the rain forest vegetation belt where rain falls for at least nine months in the past, but appreciable rainfall that could support crop cultivation is now limited to seven months within the year. This occurence has substantial implication for food security in the region. The results obtained are of inestimable value for the planning, organization and execution of agricultural activities; timely preparations can now be made to mobilise man power, seed and other relevant agricultural inputs in order to achieve effective crop yield. The results also underscores the need for enhancing irrigation development in the region; at present, irrigation development is at a sub optimal level. If the desired food security must be achieved, then appropriate measures must be implemented to enhance irrigation of crops that will suite the small holder farming commonly practiced in the region and to increase the length of growing season. The new rainfall regime observed would also warrant farmers to be encouraged to switch to crops that could be accomodated by the present growing season; government has a great role to play in order to achieve this, if food security must be achieved in the region.

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Faculty of Mechanical Engineering

STOCHASTIC VARIATION IN DISCRETE ELEMENT METHOD (DEM) FOR AGRICULTURAL SIMULATIONS

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Abstract

The diversity of physical and mechanical properties of agricultural materials makes them a good object for analysis, using stochastic variation during the discrete element modelling (DEM) of fibrous agricultural materials. Consequently, our study focuses on the use of coefficient of variation in agricultural DEM simulations. Laboratorial three-point bending, sideward compression and dynamic cutting tests were conducted to define the main mechanical parameters and behaviour of corn stalks. The effects of the different variations of coefficients (between 0.0 – 1.0 by 0.2 increments) on the quantitative and qualitative simulation results were analysed. The results of the study clearly demonstrate that the coefficients of the variation could be advantageously utilised.

Keywords

Discrete element method (DEM), stochastic variation, corn stalk.

1. Introduction

Thanks to the natural diversity of physical and mechanical properties of agricultural materials, the accurate numerical modelling of these materials provides a huge challenge for researchers. In most cases during the laboratorial or in situ tests, the parameters of interest usually show a wide confidence interval around the mean values. Nonetheless, these parameters could inordinately change in the same sample as well. To handle this problem a stochastic variation, as in the natural structures, should be used during the numerical simulations.

From the different numerical methods the discrete element method (DEM) with the Timoshenko-Beam-Bond-Model (TBBM) has the most potential for development [1]. Consequently, our study focuses on the using of the coefficient of variation in TBBM for agricultural DEM simulations.

DEM is used to investigate bulk agricultural materials widely. Keppler et al. calibrated the micromechanical parameters of a sunflower DEM model based on odometer tests so that the model can sufficiently approach the macro mechanical behaviour of the real bulk material [2]. Földesi et al. investigated the pressure relations of an oil press by DEM simulations [3]. Tamás et al. examined the soil-tool interaction and the relations in cohesive soil by using the DEM [4].

In connection with fibrous materials fewer literatures can be found. Kemper et al. investigated the iteration among grass stalk and rotation mower by DEM [5]. A special solid geometrical structure of DEM was analysed for corn stalks in quantitative and qualitative ways by Kovács et al. [6]. Several possible DEM geometrical structures for modelling of fibrous agricultural materials were compared by Kovács et al. [7]

To calibrate a DEM model, in situ and laboratorial tests are indispensable. Qin Tongdi et al. investigated the effect of different production fields on three point bending behaviour of the same maize species [8]. Sun Zhong-Zhen et al. examined the effect of moisture content on three point bending behaviour of maize stalks [9]. M. Azadbakht et al. accomplished in situ dynamic cutting test by a modified Charpy impact test to analyse the resistance against dynamic cutting force of maize stalks [10].

The results of the study clearly demonstrate that the coefficient of variation could be advantageously utilised during the simulations of agricultural materials.

2. Theory and background

Discrete element method (DEM) is developed to investigate bulk materials which contain separate parts. The definition of a DEM model is the following [11]: It contains separated, discrete particles which have independent degrees of freedom and the model can simulate the finite rotations and translations, connections can break and new connections can come about in the model.

In the field of discrete element modelling there are not so many contact models that are adaptable to modelling fibrous agricultural materials, moreover, the different DEM software products provide different contact models. In our study EDEM 2.7 (DEM Solutions Ltd.) and Timoshenko-Beam-Bond-Model (TBBM) by Nicholas J. Brown, Jian-Fei Chen, and Jin Y. Ooi were used [1].

During the bond formation a cylindrical beam is created between the predefined particles. This beam has no real volume and mass, but its mechanical behaviour follows the Timoshenko beam theory, so it can transmit forces and moments among the particles. This kind of contact can break if one of the stresses meets the predefined maximum stresses (compressive stress, tensile stress or shear stress). From the point of view of agricultural materials, the stochastic variation of the bond strength in TBBM is one of the most important features [1].

In the contact model three coefficients of variation (C_oV) for the three strengths could be used [1.]:

– ς_C: coefficient of variation for compressive strength (σ_C);

– ς_T: coefficient of variation for tensile strength (σ_T);

– ς_S: coefficient of variation for shear strength (τ).

Through the initializing of the bonds the maximum stresses are calculated with the following equations:

$$\sigma_C=S_C\cdot((\varsigma_C\cdot N)+1) \quad (1)$$

$$\sigma_T=S_T\cdot((\varsigma_T\cdot N)+1) \quad (2)$$

$$\tau=S_S\cdot((\varsigma_S\cdot N)+1) \quad (3)$$

where S_C, S_T and S_S the mean compressive, tensile and shear strength of the bonds, respectively; N is a random number from standard normal distribution [1].

With modification of coefficients of variation in range from 0.0 to 1.0 the initialized strengths of bonds show different distributions. In the following example the mean tensile strength was assumed 500 MPa and the figure shows the distribution of the bond strengths with different coefficient of variations on Figure 1.

In this study the effect of the stochastic variation of the bond strength on the simulation quantitative and qualitative results were analysed.

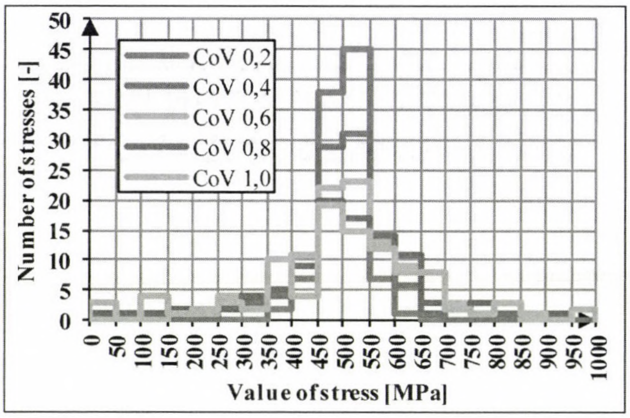

Figure 1. Initialized bond strengths with different coefficients of variations

3. Material and methods

Based on harvest and product processes of harvest-ready corn stalks the main loads (three-point bending, sideward compression, dynamic cutting) were determined. Root leaves and ears of the plant were neglected in our study so these parts were removed from the stalk before the measures.

First of all, the physical properties of the stalks (mass, moisture content, length, diameter, shape) were measured and taken down. After that laboratorial three-point bending, sideward compression and dynamic cutting tests were conducted to define the main mechanical parameters and behaviour of corn stalks. The results of the measures weren't directly usable for the modelling method so suitable data and graphs were calculated with mathematical and statistical methods for the numerical modelling.

Based on our previous study a hollow DEM geometrical structure with 18 particles was chosen for the study [7]. This geometrical model ensures detailed investigations with low computational costs. After that the DEM models of three-point bending, sideward compression and dynamic cutting were simulated with 0.0; 0.2; 0.4; 0.6; 0.8 and 1.0 coefficients of variation. The models had to be recalibrated in every case of the coefficients of variations because of the new distribution of bond strengths.

The simulation results were evaluated by quantitative and qualitative ways in order to find a right coefficient of variation that can simulate the mechanical properties and behaviour of the real plant more accurately.

4. Measures

Before each measure the necessary specimens were prepared. During the preparation, leaves and ears were pruned from the stalk and the necessary physical parameters were measured. Finally, the stalks were cut to the right size for the mechanical measures.

Analyses were conducted for the fourth internode hence the results of the study are in relation to the fourth internode. During the measurement of the physical parameters 10 plants were investigated. Water based moisture content, diameter, length and mass of the fourth internode were measured (Table 1.).

Table 1. Physical parameters of the fourth internode.

Parameters	Results
Average moisture content	51,68 %
Average diameter	18.2 mm
Average length	123.9 mm
Average mass	32.9 gr

The aim of the three-point bending test was to define the resistance against bending of the first internode. The bending diagram has three different sections: the linear section where the relation is linear between the force and displacement, the contraction section where the diagram reaches the maximum force and the bended cross-section of the internode is flattening, and finally, the plastic joint section where the bended cross-section is crashed so the resistance against the bending is decreasing gradually until the end of the bending test (Figure 2.).

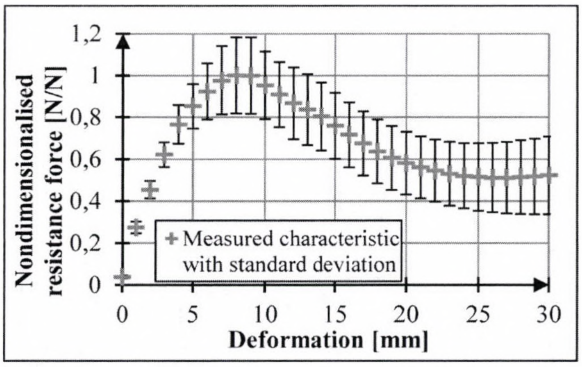

Figure 2. The characteristics of three-point bending of the fourth internode

The aim of the compression test was to determine the side pressing resistance of the fourth internode and the crossway and residual sideway deformation over the stalk length. The compression diagram has two different sections: the constant section which goes up to 35% deflection where the resistance force is close to constant, the exponential section that goes from 35% to 75% deflection where the resistance force is exponentially increasing (Figure 3.).

The aim of the dynamic cutting test was to determine the cutting work of the first internode. Ten specimens were investigated, and based on the evaluation of the results the average cutting work with standard deviation of the fourth internode was 21.92±6.8 J.

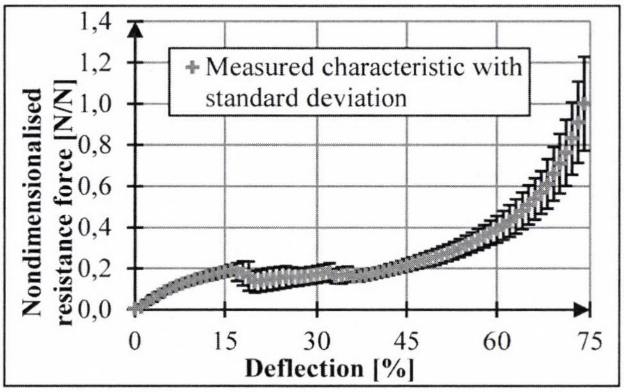

Figure 3. The characteristics of sideward compression of the fourth internode

5. Model calibration and variation

Thanks to the randomization during the bond formations, different bond strength distributions come about in different simulations despite the same set of input model parameters. Consequently, in the beginning of our study the effect of the coefficients of variation on the model calibration was analysed.

When the coefficient of variation value was 0.2; nine simulations were conducted with the same set of input model parameters: three simulations of three-point bending test, sideward compression and dynamic cutting, respectively. After the simulations the characteristics of three-point bending, sideward compression and the results of dynamic cutting work were compared.

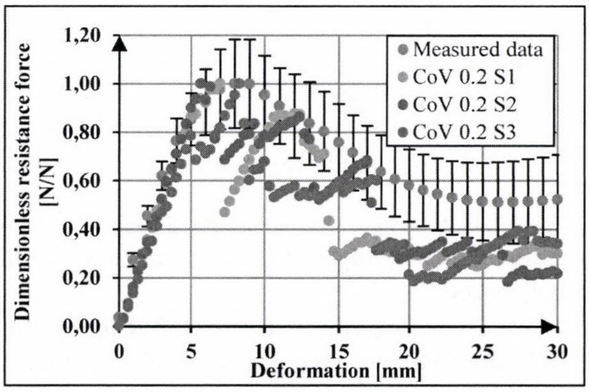

Figure 4. Simulated characteristics of three-point bending test with different distribution of bond strengths

In the course of three-point bending simulations, all three characteristics (CoV 0.2 S1; CoV 0.2 S2; CoV 0.2 S3) coincide very-well with the linear stage of the measured curve. In the middle section of the simulation process, all the simulated diagrams show sharp changes, but at the right end of the chart all of them show a nearly constant resistance force. (Figure 4.)

Based on these results, it could be declared that on the simulated characteristics of the three-point bending test significant differences could not be observed despite the different distribution of the bond strengths.

In case of the modelling sideward compression two characteristics, the CoV 0.2 S1 and the CoV 0.2 S2, provided nearly the same results. After the beginning section of the curve, both of them have two sharp drops between 10% and 25% deflections and after 25% deflection the resistance force is close to zero to 55% deflection. After that, both of them have an ascending section until the end of the simulation. The characteristic of CoV 0.2 S2 differs from the mentioned characteristics only in the beginning stage because it has one big drop, about 20% deflection, instead of two smaller ones. (Figure 5.)

Based on these results, it could be declared that on the simulated characteristics of sideward compression test significant differences could not be observed despite the different distribution of the bond strengths.

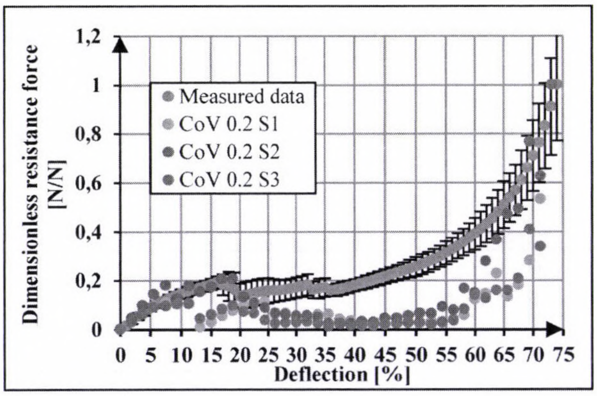

Figure 5. Simulated characteristics of sideward compression test with different distribution of bond strengths

During the comparison of simulations of dynamic cutting, only the value of dynamic cutting work could be compared.

Based on the results, it is clear that there are no significant differences among the results of simulated dynamic cutting works despite the different distribution of the bond strengths. (Figure 6.)

The simulation results clearly demonstrate that there are no significant differences among the simulated results in cases of different distributions of bond strengths.

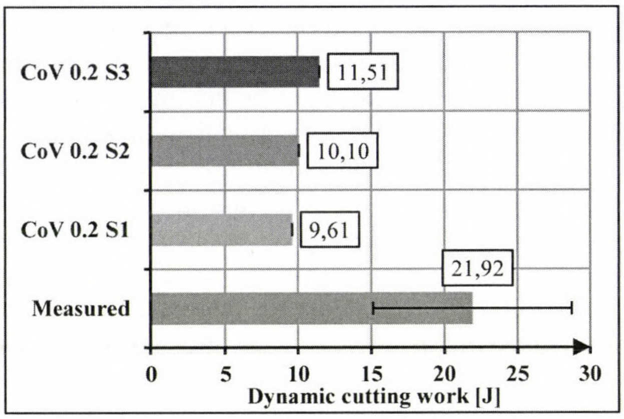

Figure 6. Simulated results of dynamic cutting test with different distribution of bond strengths

6. Quantitative results

The model was evaluated with quantitative and qualitative methods. During the quantitative method the real measure diagrams and results, from the three-point bending, sideward compression and dynamic cutting were compared with the simulation diagrams and results.

During the comparison of quantitative simulation results of three-point bending and sideward comparison the curve with best fit and smoother characteristic was searched for and naturally, through the characteristics the right CoV was searched for as well.

Based on the simulated characteristics of the three-point bending test, the following observations can be established:

–characteristics from CoV 0.0 and 0.2 present a very unsmooth curve and a very inaccurate fit except the linear stage of the curves (Figure 7.);

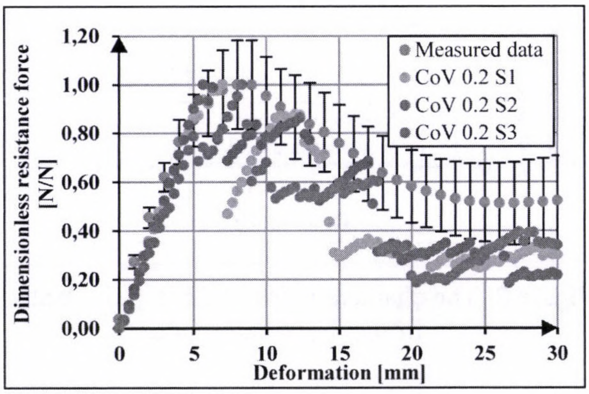

Figure 7. Simulated characteristics of three-point bending test from CoV 0.0 and 0.2

–characteristic from CoV 0.4 shows smaller drops and the most accurate fit with the measured data (Figure 8.);

–characteristic from CoV 0.6 presents a curve with smaller drops and high inaccuracy in its middle stage (Figure 8.);

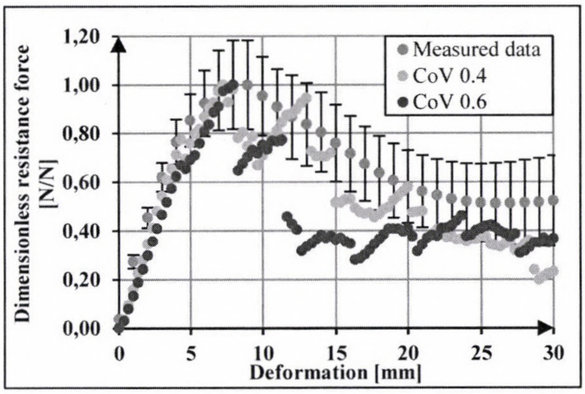

Figure 8. Simulated characteristics of three-point bending test from CoV 0.4 and 0.6

–characteristics from CoV 0.8 and 1.0 shows one or two recordable drops only and has an acceptable accuracy in all its stages (Figure 9.).

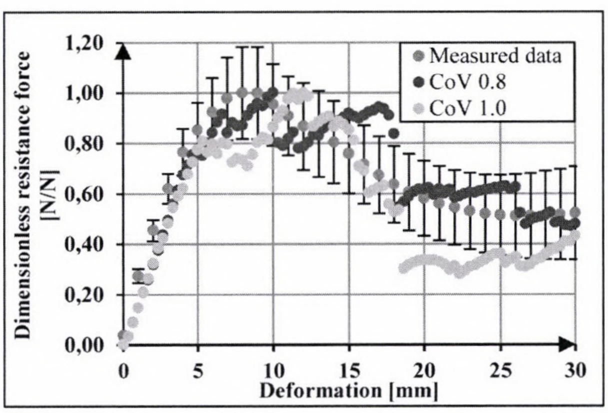

Figure 9. Simulated characteristics of three-point bending test from CoV 0.8 and 1.0

Based on the simulated characteristics of the sideward compression test, the following observations can be established:

–characteristics from CoV 0.0 and 0.2 present a very unsmooth and inaccurate curve (Figure 10.);

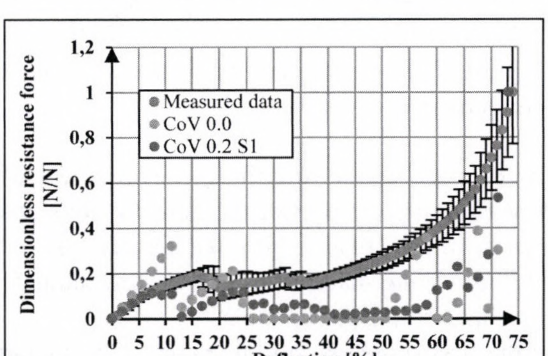

Figure 10. Simulated characteristics of sideward compression test from CoV 0.0 and 0.2

–characteristics from CoV 0.4 and 0.6 show smoother curves and they approach the measured data from below (Figure 11.);

–characteristics from CoV 0.8 and 1.0 present the smoothest and the best fit with the measured chart (Figure 12.)

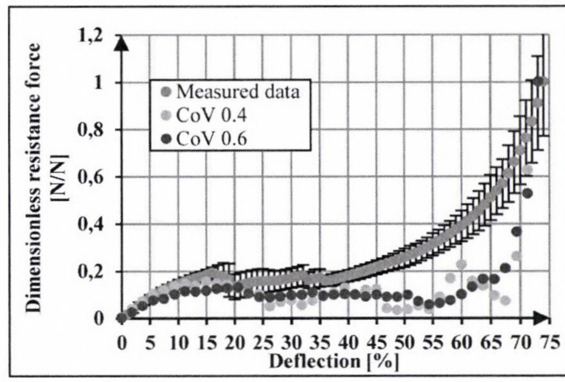

Figure 11. Simulated characteristics of sideward compression test from CoV 0.4 and 0.6

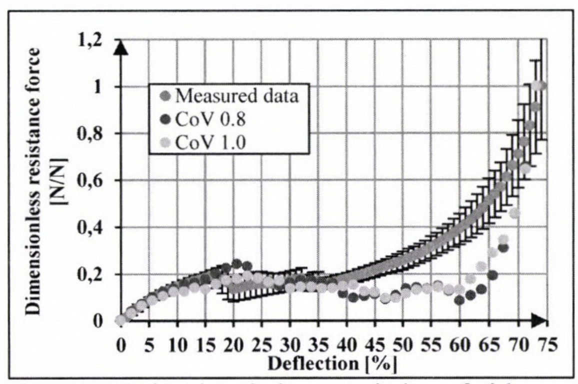

Figure 12. Simulated characteristics of sideward compression test from CoV 0.8 and 1.0

During the comparison of quantitative simulation results of dynamic cutting the most accurate result was searched for and naturally, through this result the right CoV was searched for as well.

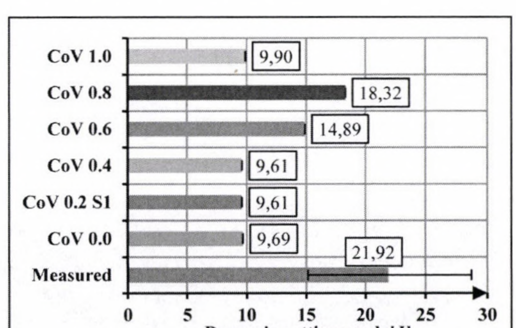

Figure 13. Simulated results of dynamic cutting test from CoV 0.0 - 1.0

Based on the simulated results of the dynamic cutting test, the following observations can be established:

–results from CoV 0.0; 0.2; 0.4 and 1.0 are practically the same with more than 50% inaccuracy (Figure 13.);
–result from CoV 0.6 is near to the lower limit of the measured dynamic cutting work (Figure 13.);
–result from CoV 0.8 is the only one that is situated between the limits of the measured dynamic cutting work (Figure 13.).

To sum up this chapter, the simulation characteristics and results from CoV 0.8 presented the best fit with the measured characteristics and results.

7. Qualitative results

During the qualitative evaluation cross-section deformations, crashes, breaks of the model were compared with the observed experiences of the real specimens.

Unfortunately, in most cases there were no noticeable differences among the qualitative results from different CoVs. From this reason in the following chapter the qualitative results from CoV 0.0 and 0.8 will be compared because simulation with CoV 0.8 provided the most accurate quantitative results.

In course of the qualitative evaluation of simulation results of three-point bending test, the shape of the modelled sample with the real specimen at the point of maximum deformation and the residual deformation of modelled sample with the real specimen was compared.

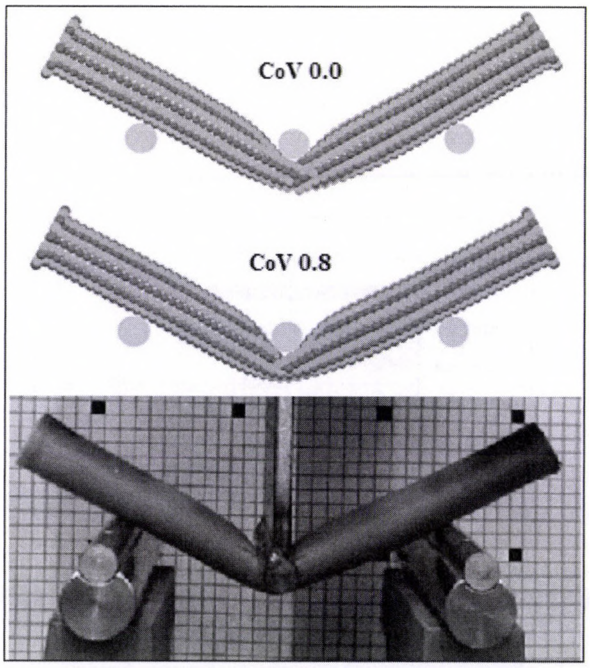

Figure 14. Simulated and real shape of specimens at the point of maximum deformation during the three-point bending test

Based on the observations during the measure, the following statements can be formed for the simulated specimens at point of maximum deformation:
–in all cases, the bended cross-sections of the modelled specimens were crashed under the loading anvil just as the real specimen (Figure 14.);
–in all cases, the bended shapes of the modelled specimens were near the same as the real specimen (Figure 14.).

Based on the observations during the measure, the following statements could be formed for the residual deformations of the simulated specimens after the process of three-point bending:

–the bended cross-section of the modelled specimen with CoV 0.0 shows less residual crash than the modelled specimen with CoV 0.8, but none of them present such a large buckle in the bending zone as the real specimen (Figure 15.);

–the residual shape of the specimen with CoV 0.0 was fully straight, in turn, the residual shape of the specimen with CoV 0.8 bended a little back (thanks to the more extended crashed zone) after the simulated bending process (Figure 15.).

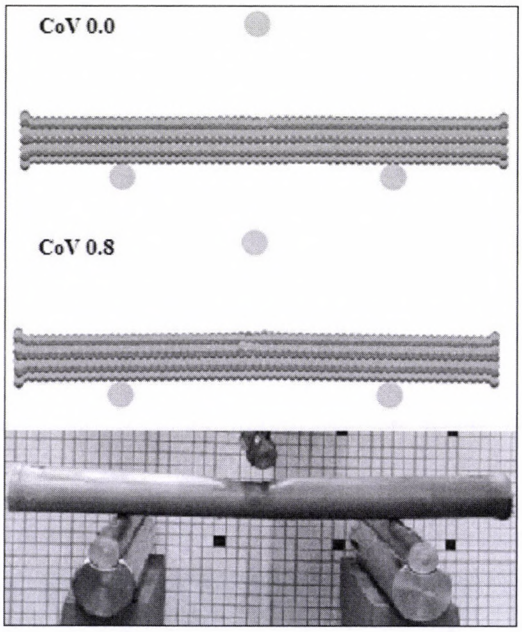

Figure 15. Simulated and real residual shape of specimens in the end of the three-point bending test

In the case of the qualitative evaluation of the sideward compression test the deformations and the damages of the cross-section were analysed.

The following statements can be formulated with the comparison of the models:
–in the first stage, the initial shape of the specimens can be observed (Figure 16.);
–in the second stage, elastic deformation took place until the first break appeared in vertical direction,

the model with CoV 0.0 could mimic the real specimen better (Figure 16.);

–in the third stage, another break appeared in horizontal direction, the vertical and the horizontal breaks could be observed clearly in the model with CoV 0.0, in turn, the breaks could not be realized in the model with CoV 0.8 (Figure 16.);

–in the fourth stage, that is the end of the compression process, the model with CoV 0.8 could better mimic the state of the real specimen (Figure 16.);

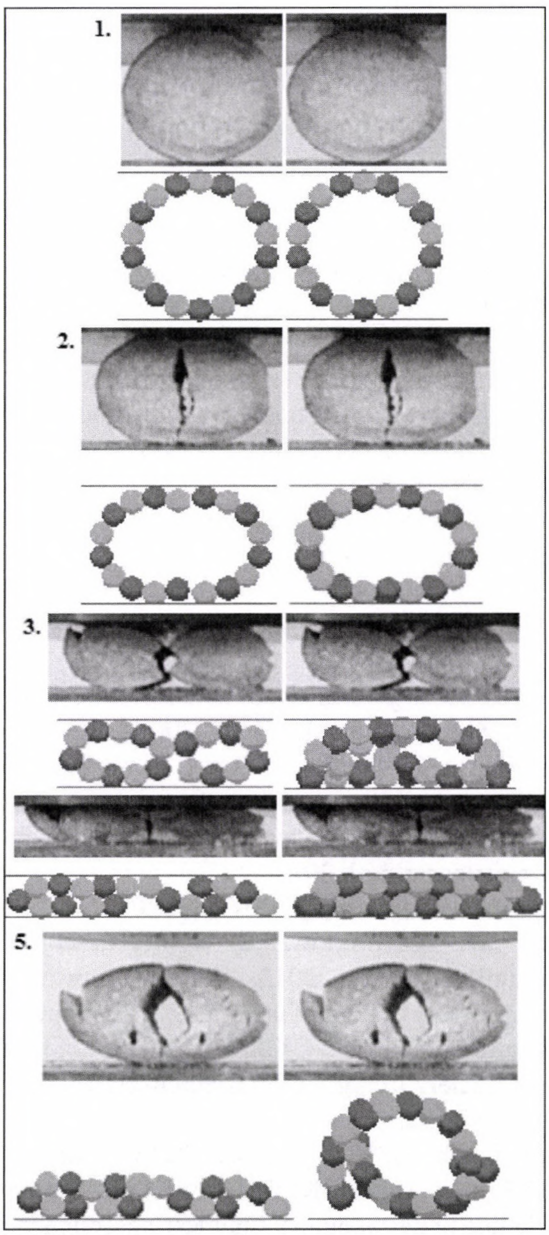

Figure 16. Simulated and real deformations and crashes of specimens during the sideward compression test, CoV 0.0 on the left side, CoV 0.8 on the right side

–in the last stage, compression clamps returned to the starting point and an elastic deformation was conducted in the real and in the model with CoV 0.8 as well, in turn, the model with CoV 0.0 showed only a minimal elastic deformation. (Figure. 16.)

During the qualitative evaluation of the dynamic cutting test the surface of cut was analysed.

The following statements can be formulated with the comparison of the models and the real specimen:

–in the models the cutting knife broke out the bottom part of the specimens, in turn, on the real specimen this phenomena was not observed (Figure 17.);

–in the model with CoV 0.0 the cutting trace has a form of "L"; in the other model it is straight aside from some fibres; the real sample had a fully straight surface of cut with some fibres as well, so from this point of view the model with CoV 0.8 mimics better the behaviour of the real specimen (Figure 17.).

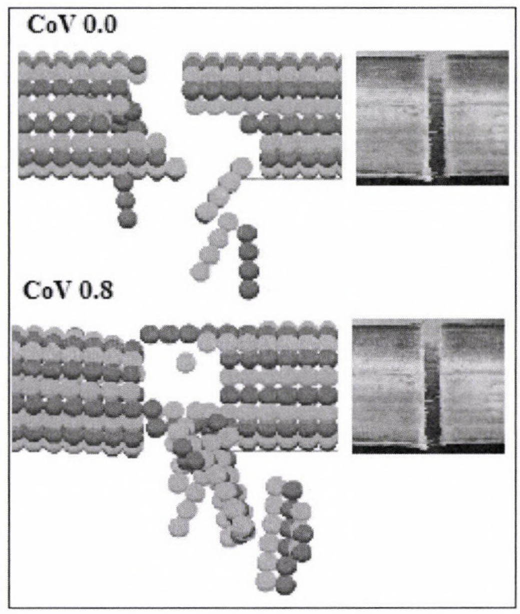

Figure 17. Simulated and real surfaces of dynamic cutting test

8. Conclusion

In our study the effect of coefficients of variation of the Timoshenko-Beam-Bond-Model was investigated in connection with discrete element modelling of fibrous agricultural materials.

After laboratorial three-point bending, sideward compression and dynamic cutting tests the necessary characteristics and results were calculated for the discrete element model.

During the model formation a hollow geometrical structure with 18 particles was chosen for the study, based on our previous research [7].

The DEM models of three-point bending, sideward compression and dynamic cutting were simulated with 0.0; 0.2; 0.4; 0.6; 0.8 and 1.0 coefficients of variation.

Based on the quantitative and qualitative evaluation of the models, the following conclusions can be formulated:

- during the calibration, there are no significant differences among the simulated results in case of different distributions of bond strengths;
- during the quantitative evaluation of all the simulated laboratorial tests, the simulation results from CoV 0.8 provided the smoothest curves and the most accurate results;
- during the qualitative evaluation of the simulated three-point bending test, significant differences between the simulation results from CoV 0.0 and 0.8 were not observed;
- during the qualitative evaluation of the simulated sideward compression test, in the first three investigated stages the simulation results from CoV 0.0 presented better coincidence with the real specimen, in turn, within the last two investigated stages the simulation results from CoV 0.8 mimics were better regarding the behaviour of real specimen;
- during the qualitative evaluation of the dynamic cutting test, the simulation results from CoV 0.8 mimics were better considering the surface of cut of the real specimen.

To sum up, the results of the study clearly demonstrate that the coefficient of variation could be advantageously utilised during the simulations of agricultural materials.

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Faculty of Mechanical Engineering

COMPARATIVE STUDY ON THE PRODUCTION PARAMETERS, ANIMAL HEALTH STATUS AND DRUG COSTS ON A COMMERCIAL DAIRY FARM

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Abstract

The ever-changing economic criteria system of the last 25 years proved to be a challenge for the Hungarian husbandry. The Regime Change, entry into the European Union, and the current trend of market globalisation cause changes and uncertainty. This results in significant tasks for experts working in the farm management. The vet profession prefers prevention instead of the classic curative activities. Knowing the technological solutions of farms is required for all these. Also, production indices and costs have to be followed in order to realise animal health management that produces an income. The dairy farm in the current analysis can be said to be sufficient in terms of animal health, taking the domestic level of herd health into consideration - and excluding calf healthcare. Furthermore, the costs of livestock drugs generate a return quickly. Based on the data of the analysis, the total specific costs of drugs are an average 23,582 HUF for each cow annually. This generated a return for an excess milk of 237.8 per cow annually. Naturally, the continuously growing market price of milk also influenced the return, which is a somewhat confusing economic circumstance, in regards to the financial efficiency of drug usage.

Keywords

animal health, drug costs, dairy production, cost-benefit analysis

1. Introduction

The ultimate goal of those who own dairy farms is to sustain the long-term profitability of their property. Therefore, they have to adapt to market demands. The Regime Change, entry into the European Union, and the current trend of market globalisation cause changes and uncertainty. This results in significant tasks for experts working in the farm management. The vet profession prefers prevention instead of the classic curative activities. Knowing the technological solutions of farms is required for all these. Also, production indices and costs have to be followed in order to realise animal health management that produces an income. The consumer and market demands are always changing, and adapting to them requires quickly executed technological changes. The fastest to react are the ones to stay standing on the market. This can only work if experts can measure expected effects during their decisions as accurately as possible, and to the greatest possible detail. Managing dairy farms demands more and more economic-related knowledge from vets, and for them to measure the consequences of their decisions on animal health. The current study aims to comparatively analyse a commercial dairy farm's production indices, animal health state and drug usage.

2. The general economic environment of bovine husbandry

2.1. Most notable changes in the dairy cow sector

In 2000, the Hungarian dairy farms gave 11-12% of the total agricultural production [1], but grew until 20% by

2012 [2]. In other words, their economic role is a very important one in agriculture. The bovine husbandry of nations, which have a modern agriculture, underwent significant changes. In spite of the constant decrease of the livestock numbers, the milk yield per cow constantly increased. This was caused by the development of genetics, and the modernisation of farm technological solutions. Though the number of dairy farms decreased, their average number of livestock increased, which means the herd size became large. The cost-intensity of modern technologies is very high, which significantly increased the amount of capital the sector needs. At the same time, the work of vets changed fundamentally as well: preventing herd health problems became the most important, by which the production of the farm can be increased [3].

2.2. Main factors determining the profit of bovine husbandry

Profit is determined by the costs and returns of production, and most notably the milk price in our case. The quantity and quality of produced milk is influenced by many factors, some of which are: the genetics, the housing technology, the herd size, the level of feeding, the rate of culling, the state of reproduction, and the animal health management. These all determine production costs which might be decreased by high-tech information technology, good farm management including efficient planning, determined and accurate employees. However, costs related to environmental protection (f. e. manure handling) and animal protection are unavoidable, due to the European Union regulations. Apart from the milk sales, calves, breeding animals, culled cows, and manure can also generate some income. If we subtract the fixed and variable production costs from the income, we get the profits [3].

2.3. Effects of diseases on the production of the dairy farm

Ferenc Kovács said the following in 1975: "an animal is healthy, if it can produce according to its genetic capacity, within the confines of being economically sound". Multifactoral diseases are caused by many correlated factors, and the general symptom of the disease is made up of the pathogens, however, risk factors do have a significant role to play, e.g. housing and feeding disorders. The most notable economic losses of dairy farming are caused by mastitis, reproductive disorders, lameness, and respiratory diseases (BRDC) [3]. Multifactoral diseases can be efficiently avoided by animal health programmes based on environmental checks [4].

2.4. Production indices and drug costs of dairy farms

Animal health technology significantly influences the production indices and drug costs of dairy farms. It's a fact that prevention is always cheaper than the curation of already existing diseases [3, 5]. Ózsvári et al. [6] compared the production indices (the quantity of marketed milk, progeny and mortality and culling rate) to animal health drug costs. They categorized the drug costs based on product groups and indication. Most of the costs were made up of drugs used to treat mastitis (45% and 50%, respectively) for two dairies, and to treat fertility problems (40%) for a third one. The costs of antibiotics were the most notable for all three farms (46.8% on average). If we take a look at the costs of antibiotics by indication, we can see that for all three herds, the antibiotics used for mastitis were the most costly (72.7% on average). The average costs of vaccines amounted to 9.5%, whereas those of disinfectants to 8.9%, hormones to 12.3%, and vitamins - nutrient supplements to 11.6%. Ózsvári et al. [6] calculated that the annual drug costs for a cow amount to an average of 10.560 HUF, the specific drug costs for mastitis to an average of 0.61 HUF/1/year, and the specific drug costs for reproduction disorders to an average of 2,425 HUF/calf/year for the three farms. The costs of drugs used for udder treatment generate a return in case of an annual surplus of 70 litres milk produced for each cow. The drug costs spent on reproduction disorders generate a return in case of an annual 0.043 extra calf for each cow.

Varga and Ózsvári [7] compared the production indices of a dairy farm with the vet drug costs for the 2000-2002 period. Out of the production indices, the marketed milk increased with the years - in spite of no change in the number of livestock. 44.9% of all drug costs were spent for antibiotics, 7.3% went to disinfectants, 13.1% to vitamins and nutrient supplements, 11.5 to hormones, and 10.9% to vaccines. The specific drug costs increased to almost 300% within three years: in 2000, they amounted to 17,400 HUF, which increased to 31,500 HUF by 2002. This can be explained by the substantial increase of antibiotics, vitamin and vaccine costs. The share of vitamins, nutrient supplements and vaccines have of all costs also increased substantially. The total drug costs for 1 litre milk increased from 3 HUF to 4.4 HUF. On this farm, the costs invested into mastitis treatment drugs generated a return in case an average 349.7 litres extra milk for each cow. The drug costs for 1 litre of milk increased, meaning the economic efficiency of drug usage decreased.

Szerémi [8] evaluated a dairy farm housing 1000 cows, based on comparing their production indices and drug costs. The amount of cows increased slightly between 2003 and 2005, which also caused milk production to increase. The drug costs for one cow was 17,716 HUF, amounting to 2.14 HUF for a litre of milk. Categorized by indication, the preventive drugs (vaccines, disinfectants) were the most significant (with 36.8%) on the farm. This was followed by drugs used to treat reproductive disorders (25.9%) and those used to treat mastitis with 23.3%. 41% of all costs were used for antibiotics. The amount of disinfectants was 24%, which is over three times as much as the previous data. Hormones took up 10% of the costs, whereas vaccines were accounted for 13%. Szerémi [8] detailed the preventive drugs and antibiotics categories according to indication and active substances. 45.9% of preventative drugs in this analysis were udder disinfectants, and 54% were drugs used for mastitis. According to the average data of analyses conducted at Hungarian dairy farms, total drug costs consist of 45.2% antibiotics, 12.8% disinfectants, 11.7% hormones, and 10.6% vaccines. 68.4% of antibiotics on average are used for udder treatment [3, 6, 7, 8, 9]. Based on the literature, we can say that the production indicators and drug costs are very varied. Therefore, we think that there's a very good opportunity for increasing economic efficiency via well-designed animal health programs.

3. Materials and methods

During the research field work, we analysed a southern Great Plains dairy farm, where an average of 732 cows were kept during the analysis timeframe. 70% of the animals were of pure Holstein Friesian breed, and the remaining were crossbreeds of Norwegian Reds. The dairy farm had six production stables, each with 120 cattle capacity and deep litter. Four of these are modern, large internal height ones outfitted with collaring machines. Before calving, cows are kept in a dry stable for 7-8 weeks, along with heifers in calves. Two weeks before the expected time of calving, the animals are moved to the preparation area, and into the calving area right before calving, which is in the same building. The stable is loose-housed with deep litter, well-lit, has a collaring machine, and contains crucibles for calving and operations. There are 5-10 cows waiting for calving in the calving area on average. 3 days after calving, if the cow is capable of production according to the checkups, it's released from the calving area, and led into production stable No. 1. Her state of health is monitored every day for 30 days after this. Calves are separated from their mothers 1 hour after birth, after they consumed at least 1.5 litres of colostrum. After this, the calves are raised in special cubicles until they're 10-14 days old, from where males are sold for further keeping. Heifers are moved to the new large internal height calf raiser constructed in 2013, which houses 12 × 20 calves total. The four compartments in the centre are outfitted with Westfalia milk feeders offering milk substitute from a pacifier for each group. 2-3 weeks after a selection process, they're moved to the calf group raising area with deep litter. When they reach 6-8 months of age, they're herded to the neighbouring stables for youngsters, from where they're conceived at 15 month age, in case their body size is adequate. After positive pregnancy check, they're sent to the neighbouring dry cow stables with the other cows.

The milking is done using an old Westfalia 2×9 fishbone milking machine with a low milk canal, until the new Gea carousel system milking house is installed by mid-2015. The cows, the young and the separated calves are fed with monodiet, the group feeding is done from feeding tables. The production group is fed two times a day, whereas the others are fed once a day. Refreshing and retracting the Total Mixed Ration (TMR) is done 4-5 times a day. The TMR is distributed using a 12 m^3 Eurocomp feeding car pulled by a tractor, linked to a computer and a scale. The feeding materials used on the farm are: corn silage, alfalfa silage, grass bale silage, green wheat, triticale bale silage, alfalfa hay, grass hay, sugar beet slices and sweet pickled corn by-products.

The owners of the farm find feeding very important with a high fibre content, constant compound and homogeneous TMR based on exceptional roughage. They also set the bedding exceptionally well. They don't aim for an outstanding milk production, however, their cows' life expectancy is high, while the mortality and culling are kept low. The herd is officially free of tuberculosis, brucellosis and leucosis, and leptospirosis does not take place. They sold many in-calf heifers to the post-Soviet states, and purchased young heifers and calves with exceptional genetics from the Netherlands to replace them.

In the first part of our analysis, we collected the production indices of the dairy farm for the 2012-2014 period. We calculated the average drug costs of the herd by multiplying their amounts with their net prices of the three years. This process was done in accordance with other references [3, 6, 7, 8, 9], and sorted them by year, product groups and indication. We analysed how the costs of antibiotics were in detail, based on indication and active substance. To facilitate comparisons, we calculated the annual drug costs for one cow and one litre of milk. We evaluated the correlation between drug usage and production indices. We compared the milk production and reproductive parameters to the udder health and fertility treatment drug costs. We also compared the mortality rate with the total drug cost per cow, and the calf drug costs per calf to the calves' mortality rate. Afterwards, using all the collected data, we calculated the recovery of drug costs in the herd.

4. Results and discussion

4.1. Comparative analysis of production indices and drug costs on the dairy farm

We calculated the annual udder health drug cost per cow and the annual fertility treatment drug cost per cow, and compared them to the related production parameters. This way, we were able to analyse the efficiency of drug usage. When evaluating the efficiency of calf health management, we compared the annual drug costs per calf to the calves' mortality rate. In order to evaluate the total drug usage of the dairy farm, we compared the cows' mortality rate to the annual drug costs per cow.

4.1.1. Specific drug costs and production indices

The specific udder health drug costs are the quotient of the annual udder health drug cost, and the quantity of marketed milk in a year. When calculating the annual fertility treatment drug cost, the given year's amount of drugs used to treat reproductive disorders has to be divided by the total number of progeny (calves) [3].

Table 1. Udder health and fertility treatment drug costs

Indicator	2012	2013	2014	Average
Marketed milk (l/year)	4,245,589	5,267,421	5,290,512	4,934,507
Total udder health drug cost (HUF/year/farm)	3,428,303	3,498,727	3,766,572	3,564,534
Udder health drug costs (HUF/l/year)	0.81	0.66	0.71	0.72
Progeny (calves/year)	681	639	842	721
Total fertility treatment drug cost (HUF/year/farm)	2,495,330	2,305,795	2,174,875	2,325,330
Fertility treatment drug costs (HUF/calf/year)	3,664	3,608	2,583	3,227

In the case of the specific udder health drug costs (Table 1.), we can see a 18.5% decrease in 2013, which was caused by a more than one million litres increase in milk production. However, the udder health drug costs per litre increased by 7.6% in 2014. This was caused by the increase in costs of udder treatments, while the milk produced that year was barely more than in the previous year. Compared to the average 0.72 HUF/l on this farm, the previous Hungarian surveys showed 0.6 1 HUF/l/year [6] and 0.5 HUF/l/year [8] udder health drug cost/litre milk. These are 15-20% lower than our results. This difference might be because the dairy herd has lower than average lactatitional milk production. We can see how the status of udder health in the herd is unstable, since after the remarkable improvement in the middle year, it slightly deteriorated again in 2014. During the entire three year long period of the survey the milk production increased by nearly 25%, but the total drug cost barely increased by 10%, thus the specific udder health drug costs decreased by 12.3%.

The annual fertility treatment drug costs (Figure 1.) showed near identical data in the first two years - 3,664 HUF and 3,068 HUF per liveborn calf. However, in the third year, this index decreased by nearly 30% - to 2,583 HUF per calf, which was was caused by the 30% increase in the number of liveborn calves. The latter value is also a bit higher than the value calculated by Ózsvári et al. (2003) - 2,364 HUF/calf/year. The efficiency of drug usage to treat and prevent reproductive disorders in the surveyed three years is hard to evaluate. The company sold in-calf heifers to the east multiple times, and purchased calves and in-calf heifers from the Netherlands. The evaluation of data was scrambled due to the calving of these animals that did not happen, or happened in excess. Anyway, the analyses say that if the herd fertility status deteriorates, the fertility treatment drug usage increases. If we also take the previously shown production data into consideration as well, we can see that due to the high number of pregnant heifers that calved, further increase in milk production is expected.

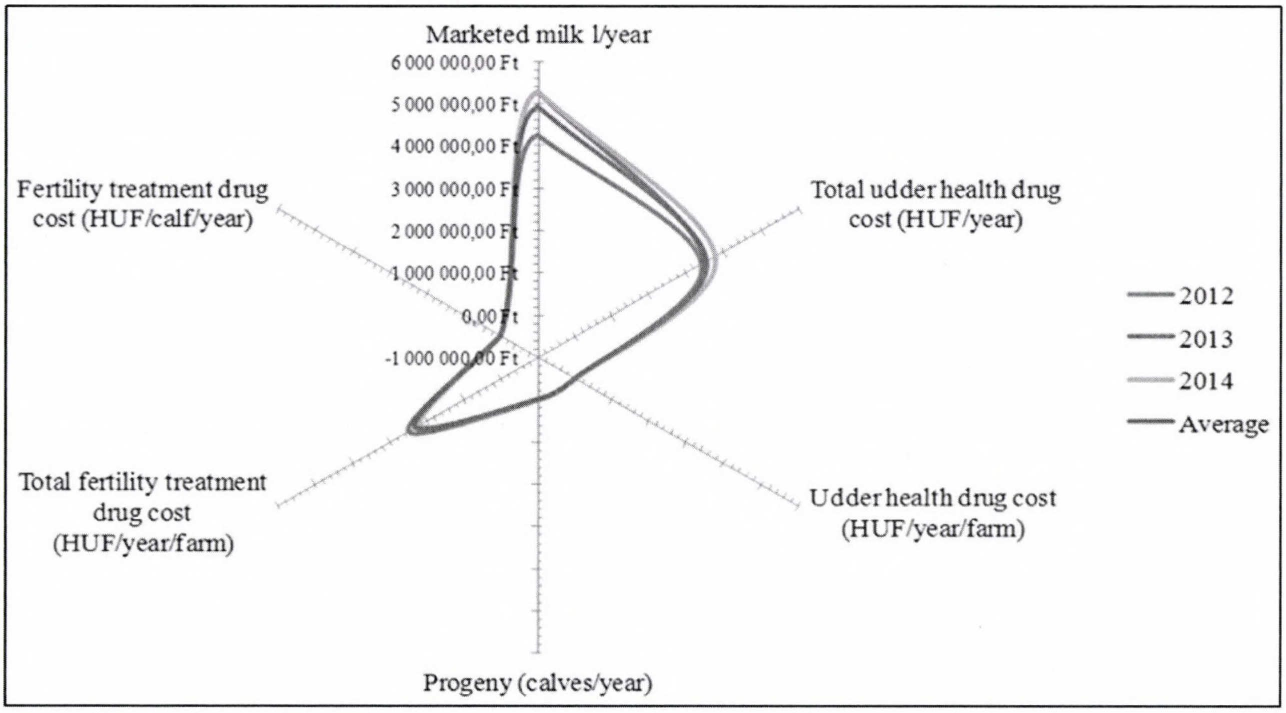

Figure 1. Trends in the annual fertility treatment and udder health drug costs

4.1.2. Correlations between drug costs and mortality rates

We also calculated the drug cost per calf, which is the quotient of the yearly costs of antibiotics used to treat calves and the annual progeny (Table 2.). After this, we evaluated the correlation between calf mortality rate and calf health management drug costs. We also calculated the costs of drugs used to prevent and treat diseases of calves until they became 6 months old, which was an average of 2,286 HUF.

Table 2. Annual total drug cost per calf/cow and mortality rates

Indexes	2012	2013	2014	Average
Calf mortality rate (%)	4,1	8,9	10,8	7,9
Antibiotics cost per calf (HUF/calf/year)	119	741	742	534
Drug cost per calf (HUF/6 month old calf/year)	1,708	2,562	2,588	2,286
Cow mortality rate (%)	4.1	2.6	3.4	3.4
Drug cost per cow (HUF/cow/year)	22,984	24,834	22,928	23,582
Cow culling rate (%)	18	21.2	19	19.4

The calf mortality rate increased by more than 116% in the second year of the analysis. The drastic increase (more than 520%) in the antibiotics cost cannot be verified by the mortality rate. The amount spent for antibiotics didn't increase significantly in 2014, but the mortality rate further deteriorated by 21.3%. Based on the evaluation, we can say that the calf raising technology, and its preventative and treatment protocol have to be changed on this dairy farm. The annual total drug cost per cow on this dairy farm reached an average of 23,582 HUF. The analyses of Ózsvári et al. (2003) measured much less – 8,000 to 12,000 HUF on average – whereas Szerémi (2007) measured 17,716 HUF. Varga and Ózsvári (2004) also found a 31,500 annual total drug cost per cow in their analysis. The dairy farm showed a nearly identical value – 22,984 HUF and 22,928 HUF for 2012 and 2014 respectively – in our analysis. However, for the year 2013, the costs increased by more than 8% - up to 24,834 HUF. The average mortality rate for the three years was 3.4%, which is below the 5.2% value Ózsvári et al. (2003) calculated in their former analysis.

4.1.3. Return on drug costs

We calculated the return on drug costs in order to evaluate the financial efficiency of herd health management on the farm. As part of this, we calculated how much extra milk results from the total udder health drug costs, how many extra calves result from the total fertility treatment costs, and finally, how many litres of extra milk per cow is worth as much as the total drug cost per cow annually. The calculations required the average buy-up prices of raw milk in the given years. In the case of the dairy farm, this price was 89.6 HUF for 2012, 101.6 HUF for 2013, and 106.3 HUF for 2014. The market price of a suckling calf for the first two years was set to 45,000 HUF. In the third year, calves couldn't be sold in their first two weeks of their life, due to bluetongue outbreaks in Hungary. This resulted in a higher calf market value of 50,000 HUF which was used in the calculation for the year 2014. It is because of that the average market price of calves sold finally at the end of 2014 was higher, but their liveweight price per kilogram didn't even reach half of the previous suckling calf price, as those were sold when they were 8-15 weeks old. The data is summarized in Table 3.

Table 3. Return on drug costs

Indices	**2012**	**2013**	**2014**	**Average**
Udder health drug cost (HUF/cow/year)	4,862	5,085	4,684	4,877
Milk price (HUF/l)	89.6	101.6	106.3	99.2
Return (l/cow/year)	54.3	50.0	44.1	49.2
Fertility treatment cost (HUF/cow/year)	3,539	3,351	2,705	3,198
Market price of a calf (HUF/calf)	45,000	45,000	50,000	46,667
Return (calf/cow/year)	0.08	0.08	0.05	0.07
Drug cost per cow (HUF/cow/year)	22,984	24,834	22,928	23,582
Return (l/cow/year)	256.7	244.4	215.70	237.8

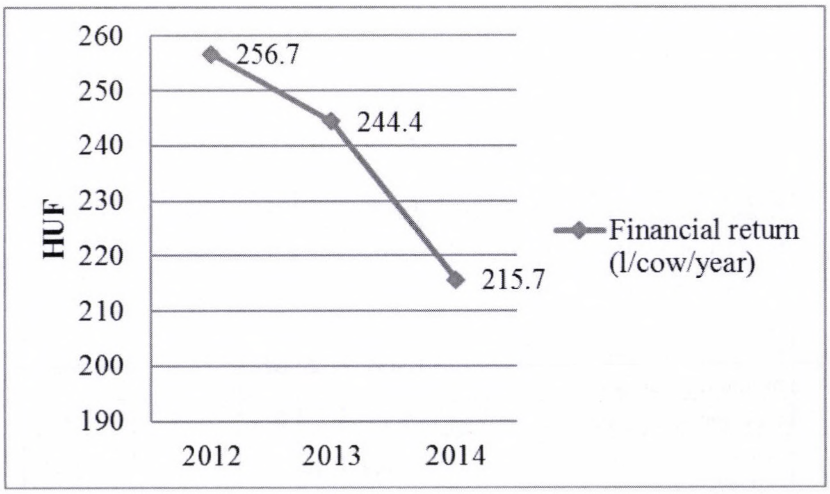

Figure 2. Return on total drug costs

The costs of udder health drugs generate a return in case of an excess milk of 42.9 l for each cow, which is much less than the amount either Ózsvári et al. (54.9-96.8) [6] or Szerémi (63.28) [8] calculated in their studies. One of the main reasons for this is that when we conducted our research, the price of milk was more than 50% higher. The buy-up price of raw milk constantly increased during the three years of our analysis, while the costs of udder health drugs increased by 5% in the second year, but decreased by 8% in the third year. Based on all this, we can understand how the costs of drugs generated a return with much less extra milk. The higher costs of 2013 were compensated by the higher buy-up price of milk. The fertility treatment drug costs generate a return, if there's an annual 0.07 extra calf born per cow. This kind of cost decreased by 23.5% in the surveyed time period. As the market prices of calves only increased by 11%, we can explain how the number of extra calves required to recover the drug costs decreased from 0.07 to 0.05 calf/cow/year. The costs spent for fertility treatments in Ózsvári et al. [6] generated a return more easily, with 0.04 extra calves. However, Szerémi's [8] return was much higher, 0.12. The annual drug costs per cow for the three years generates a return for 237.8 litres of extra milk per cow. The drug costs per cow for 2013 were 8% higher compared to those of 2012 or 2014. The annual market price of milk increased each year, which caused the return to be generated even with nearly 16% less extra milk (Figure 2). The 349.7 l milk/cow/year annual figure calculated by Varga and Ózsvári [7] is substantially higher than that we calculated. However, Szerémi's [8] result of 279.4 l is much closer to the data we calculated in this analysis.

5. Conclusions

Summarily, we can conclude that apart from calf health management, the herd health management on the farm is adequate, and the drug costs are recovered quickly (though admittedly, the high milk prices also helped in the surveyed period). The goals of the dairy farm's management is to achieve the calf health management indices of 2012, the milk production parameters of 2013, and the number of cows and calvings of 2014 from 2015. The tight cooperation of experts on feeding, animal hygiene, milking, reproduction and herd health management is needed for completing these goals.

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RECENT APPLICATIONS OF THE RENEWABLE ENERGIES

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Abstract

Renewables excluding large hydro accounted for 48% of new GW capacity added worldwide in 2014, so the renewable energies increased to 15.2% of world cumulative generation capacity, from 13.8% in 2013. In the EU the new version of the Renewable Energy Directive (RED) distributes the 10% cal. biofuels target into a share for crop-based biofuel (limited at 7% cal.) with the rest to be met with another biofuels and renewable electricity containing multiple counting possibilities. [2,3] For ethanol fuel, more growth could theoretically arrive from an extending of E-10 in EU member states. Unnecessary to discuss that an outlook for a post-2020 biofuels target at the EU level does not valid. [1, 5] In our country and world-wide the amount of waste is growing rapidly due to economic development. It is true that the amount of selectively collected waste is also increasing and also the quantities of secondary materials as recycled materials quantities - so they can get back into the manufacturing process – however it is an important task to dispose of the waste at an up-to-date and environmentally friendly location. The theoretical and practical phenomenon confirms that processing the generated waste by modern European Union-compliant technology systems can be used as alternative energy instead of fossil energy sources to produce electricity and heat.

Keywords

renewable energies, blending ratio, bioethanol fuel demand, landfill gas, municipal solid waste

1. Introduction

The research fields at our Technical Institute, on the Engineering Faculty, of the University of Szeged are as follows: the development of the combustion characteristics of the bioethanol propellant and the change, brought on by the utilization ratio, in operating factors, also the garbage lot's extraction of landfill gas and its energetic utilization. During the extraction of the landfill gas, due to change in the methane content values, which influence the energetic utilization, we examined the landfil gas values and later on we plan to use it in our experimental engine.

For this project two different manufacturer's bioethanol fuels were assessed with regard to their combustion behaviours by unchanged settings. In order to implement the objectives of research task the comparative analysis were made with two different manufacturer's bioethanol fuels (E85 Sample 1., E85 Sample 2.) and their blends in the engine testing brake [3].

Our aims were under the landfill gas test to examine the quality and quantity parameters of landfill gas changes with regard to the average temperature interval, relative humidity, wind speed interval, precipitation and the change in the organic matter content of the waste disposed. The external characteristics of the refuse dump and its environment were relevant such as weather data between which I looked for connections by mathematical statistical methods.

The connections between the examinations of the bioethanol and landfill gas are the following:

1. Possible practical applications of energetic utilization, from the perspective of the product, by-product and waste produced in the agricultural and communal sector [2, 21, 22].
2. It meets the requirements of the domestic and EU directives' admixture quota, and the regulations in effect, which state the rules regarding a garbage lot's extraction of landfill gas and energetic utilization. Thereby reducing the use of fossil fuels in the communal sector.

3. Due to the viewpoints of environmental protection regarding bioethanol, and in the case of the operation of landfill gas, we expect improvement with emission limit values, and we also expect the mitigation of Greenhouse gas emissions [4, 16, 17, 19].

2. Material and Methods

Taking into account the energetic utilization, the examinations conducted with bioethanol were the basis for the subsequently designed, landfill gas utilizing, experimental Otto engine. In this case, both fuel types' stress-examinations can be conducted, but until this is done, we have to ensure the efficiency of the landfill gas's production.

Our three short-term tests were operated with commercial gasoline and two different bioethanol fuels (E85 Sample 1., E85 Sample 2.), and their 25%,50%,75% blends with gasoline to compare the IC engine behaviours by unchanged settings. The measuring apparatus contains– a Honda GX 160 type (one vertical cylinder, 160 ccm, four stroke, air cooled,) gasoline engine, equipped with Energotest-MMP-4 type electric-brake and a computer based control and evaluating system connected to it [3, 6] (Figure 1).

The test was based on three short-term runs operated with commercial gasoline (reference) and two different bioethanol fuels and their blends with the aim to compare the internal combustion engine behaviours by unchanged settings.

The engine test was made according to directives of ECE 24 standard, so the engine was fitted with the original intake and exhausting systems and these drove the moving parts. The measurements were made in 23 operating points between 1400 rpm and 3600 rpm. The values of torque (M) and the effective power (Peff) were measured in case of full throttle and fixed dispenser lever position in every operating point. After selecting a given operating point the control of the measurement, together with the collection and the evaluation of the data are completely automated. (Energopower Software) [4, 6].

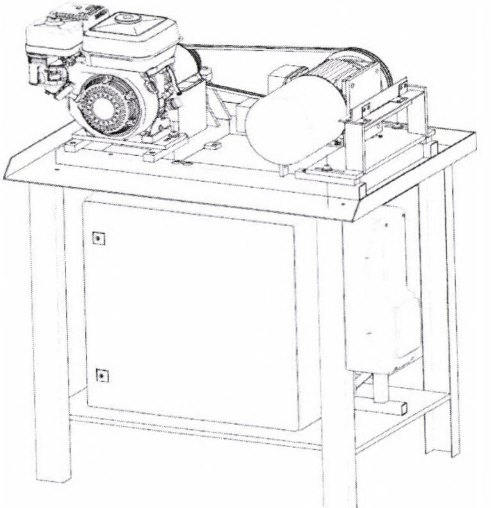

Figure 1. MMP-4 „Electric brake"

The elements of landfill gas extracting system are the following: gas wells, gas collecting pipes, gas controller unit, compressor unit, torch, container with gas engine, meteorological station. The collection of landfill gas is with the help of gas wells (Figure 2).

At the beginning there were low drainage gas wells used at the refuse dump but because of their sinking and deformation the effectiveness of gas extraction was impeded. They converted to upper drainage gas wells

which are only built after the dump is completely filled or reached a certain height. It does not interfere with the operation and good quality landfill gas is attainable [12, 13, 14, 15].

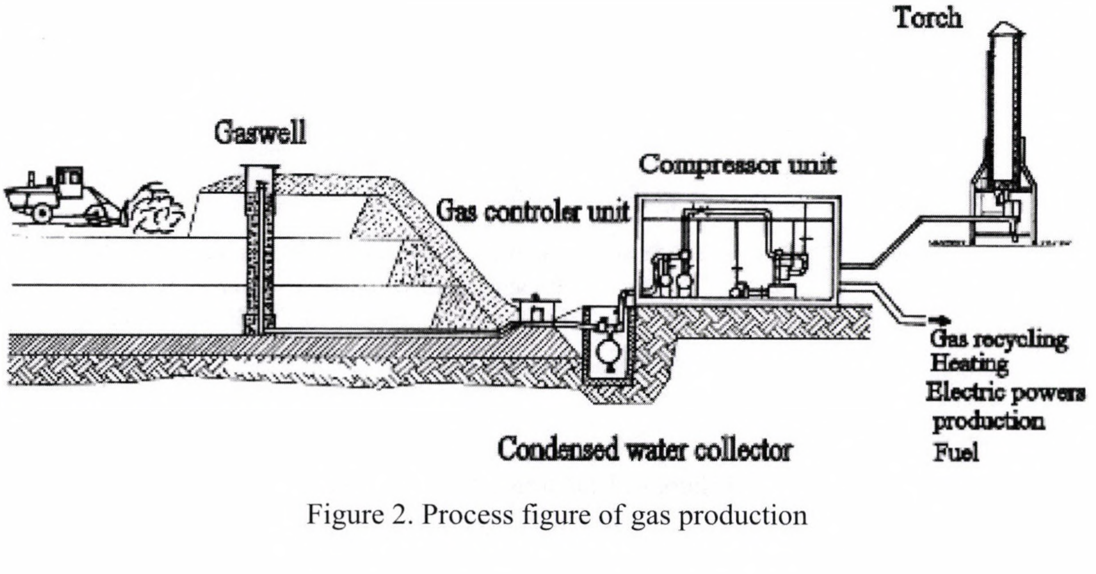

Figure 2. Process figure of gas production

At the communal solid waste refuse dump of the "A.S.A Hódmezővásárhely Köztisztasági Ltd." a computer data collection system and a measuring system is available to examine the quality and quantity of landfill gas. (Fig. 3.)

When preparing the measuring system three measuring points were established. Measuring point 2 is situated at the vacuum pump. Pressure values can be measured in front of and behind the pump, and thus the amount of the pressure difference can be calculated [12, 13]. From the pressure difference flow rate of the extracted landfill gas without pipe friction can be calculated and then, with the pipe diameter, the amount of the produced landfill gas. [9, 10, 11]

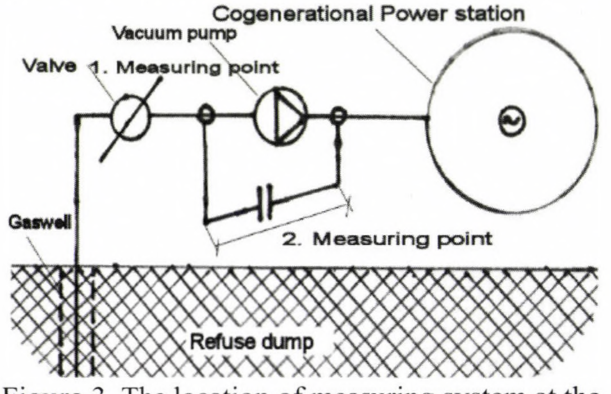

Figure 3. The location of measuring system at the refuse dump [7, 8, 9]

For diagnosing the degradation process in the refuse dump and optimizing energy recovery I we used a GA2000 type NDIR (Non Dispersive Infra Red) analyzer, working in the medium infrared region.

The data was statistically processed with SPSS for Windows 11.0 program was used. The data was processed by the method of analysis of variance. Homogeneity was examined with the Levene-test. When comparing the group-couples Tamhane test (in case of heterogeneity), and LSD test (in case of homogeneity) were applied. The tightness between variables was determined by linear regression analysis. In our examinations we calculated the necessary number of data by using a method by [17].

3. Results

Deviations in the combustion behaviour and the functions of the engine control unit are quantifiable at the test bench. For the two bioethanol (E-85) fuels tested their torque and effective power parameters were less than the reference E-95 values. Figure 4 shows the relations between torque and fuel types and Figure 5 describes connections between effective power and fuel types. We established more less values in case of both parameters (less, than 50%), which can explain with lower calorific value (26,7 MJ/kg) and stoichiometric ratio (8,97) of bioethanols opposite gasoline' same parameters (43MJ/kg and 14.7). According to the measurements our statement is that as the bioethanol content increased the effective power and the torque reduced [3, 4] (Figure 6 and 7).

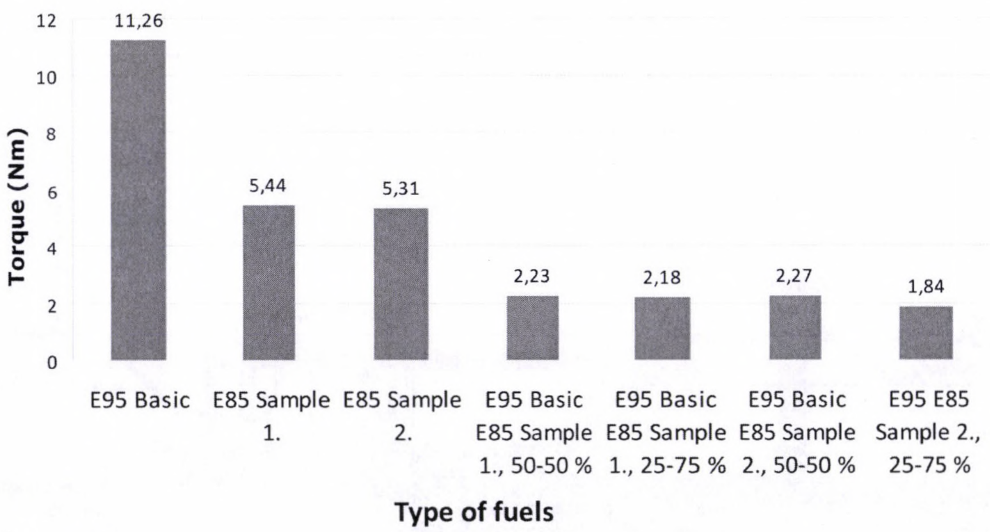

Figure 4. Relations between torque and fuel types

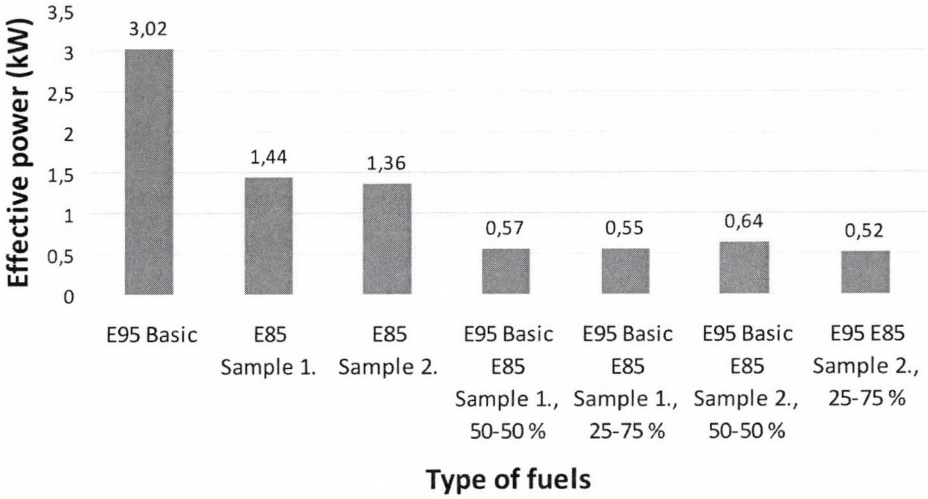

Figure 5. Connections between effective power and fuel types

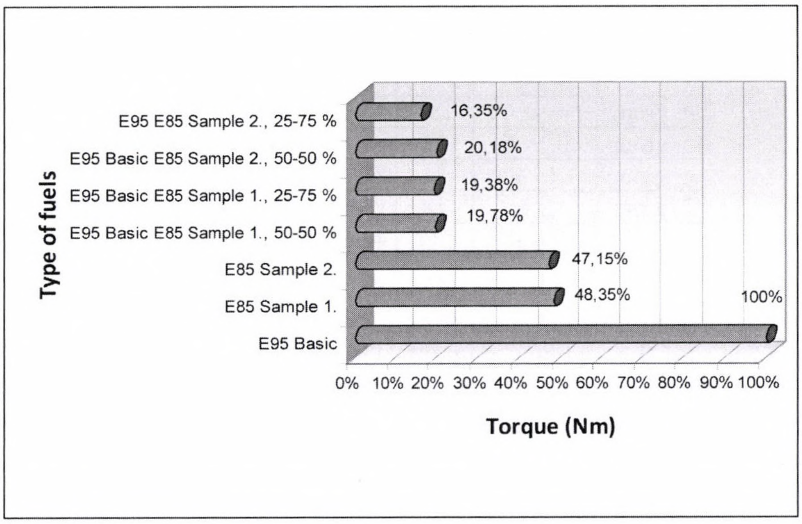

Figure 6. Changes between torque and fuel types

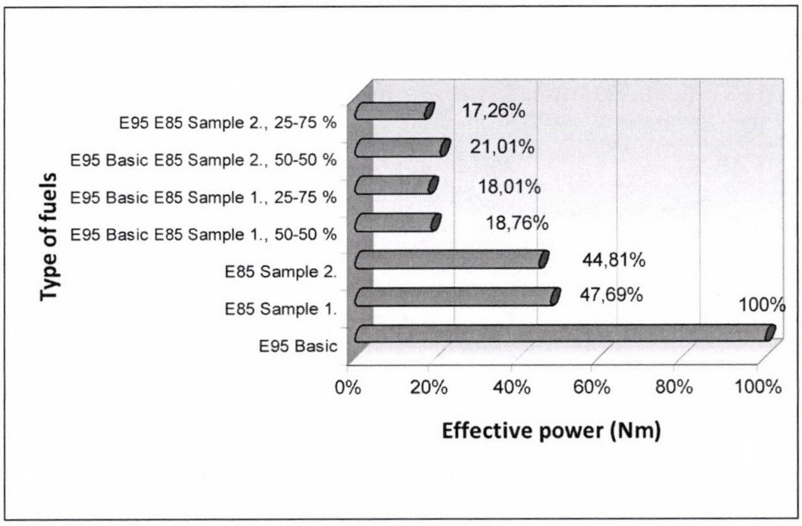

Figure 7. Changes between effective power and fuel types

Changes of the quantity parameters of landfill gas with regard to the depression used

In the first part of our examinations We tried to find a connection between the vacuum used and the methane content of landfill gas extracted from the refuse dump. Our results can be seen in Table 1. We took my measurements according to the barometric pressure by using a GA2000 landfill gas measuring device with regard to the environmental conditions of pressure. Minimum and maximum data are between the rates of 1-68 CH4. In the group with the most elements in it ((-0,9)-0) we found 52,44% methane content. The worst rate, 43,34% methane content, was found in the 2nd group ((-2,9)-(-2)), in the 1st group with 45 measurements we found 45,47% methane content. As it can be seen from the results, in the cases of groups 4, 5 and 6 the average methane content is between 51,15-54,11% because of the vacuum used. In this case the applied rate of vacuum was between (-0,9)–1,9 mbar [20, 24].

Table 1. Results of the connections between the volume of extraction and methane content

Pressure group	Volume of extraction [mbar]	n [unit]	CH_4 mean [%]	Coefficient of variation CV% [%]	Std. dev. [%]
1. group	≤ (-3)	45	45,47	32,82	14,92
2. group	(-2,9) - (-2)	58	43,34	33,94	19,04
3. group	(-1,9) - (-1)	95	46,15	31,73	14,64
4. group	(-0,9) - 0	180	52,44	21,58	11,31
5. group	0,1 - 1	72	54,11	15,97	8,64
6. group	1,1 - 1,9	41	51,15	34,47	17,63
7. group	≥ 2	18	50,87	39,76	20,22
	Total	517	49,67	28,82	14,31

At gas wells where the extent of aspiration is over (-0,9 mbar) the larger vacuum the methane content lowers so the elements of the gas extraction system have to be under continuous observation (Fig.8). Standard deviation in the whole test range was s=14,319%, coefficient of variation value was changeable, CV%=28,82%. In the 4th group in the measuring range with the highest number of elements ((-0,9)-0mbar) CV%=21,58% proved to be moderately volatile at 52,44% average methane content. In case of the 5th group in the 0.1-1 range CV%=15,97 because standard deviation is s=8,64% and the changes of minimum and maximum values show 31-68% of methane content.

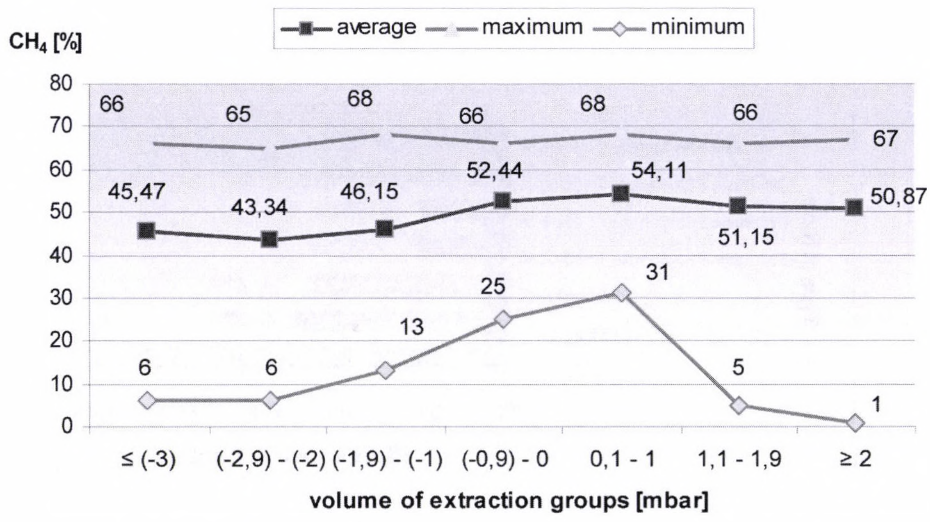

Figure 8. Results of the connection between aspiration groups and methane content

Analysis of variance proved significant results between the group pairs as the level of significance is P<5% for the examined parameters. In case of the homogeneity tests the samples showed heterogeneity so We use the Tamhane test. Results of the analysis between the groups can be seen in Table 2. The biggest difference is between group 5 (0.1-1) and group 2 ((-0.9)-0) the difference was 10,77% methane content. There was also a big difference between group 4 ((-0.9)-0) and group 2 (-2.9)-(-2) in this case methane content difference was 9,11%. From the Table 2. you can see that the smallest difference, 0,29% methane content, is between group 6 (1.1-1.9) and group 7 (≥2). There are significant differences between group 4 and group 2, P<5%, and the significant difference between group 3 and group 4 is P<1%. From the processed data we can conclude that under -0.9 mbar pressure there is no significant difference but in case of higher pressure methane content values get worse [23, 24, 25].

Table 2. Differences in the methane content of the examined groups and group pairs results

Pressure group	1. group ≤(-3)	2. group (-2,9)-(-2)	3. group (-1,9)-(-1)	4. group (-0,9)-0	5. group 0,1-1	6. group 1,1-1,9	7. group ≥2
1. group	-	ns	ns	ns	*	ns	ns
2. group	2,13	-	ns	*	**	ns	ns
3. group	0,68	2,81	-	**	**	ns	ns
4. group	6,97	9,11	6,3	-	ns	ns	ns
5. group	8,63	10,77	7,96	1,66	-	ns	ns
6. group	5,68	7,82	5,01	1,29	2,95	-	ns
7. group	5,4	7,53	4,72	1,58	3,24	0,29	-

In case of all gas wells We carried out a linear regressive examination taking both methane content and volume of aspiration into account. Its results can be seen in Figure 9. Change of methane content in relation to the vacuum used can be described by the following equation: y=3,5607x+51,72, R2=0,2644. Correlation coefficient is r=0,52. The closeness of coherence shows a centralized correlation.

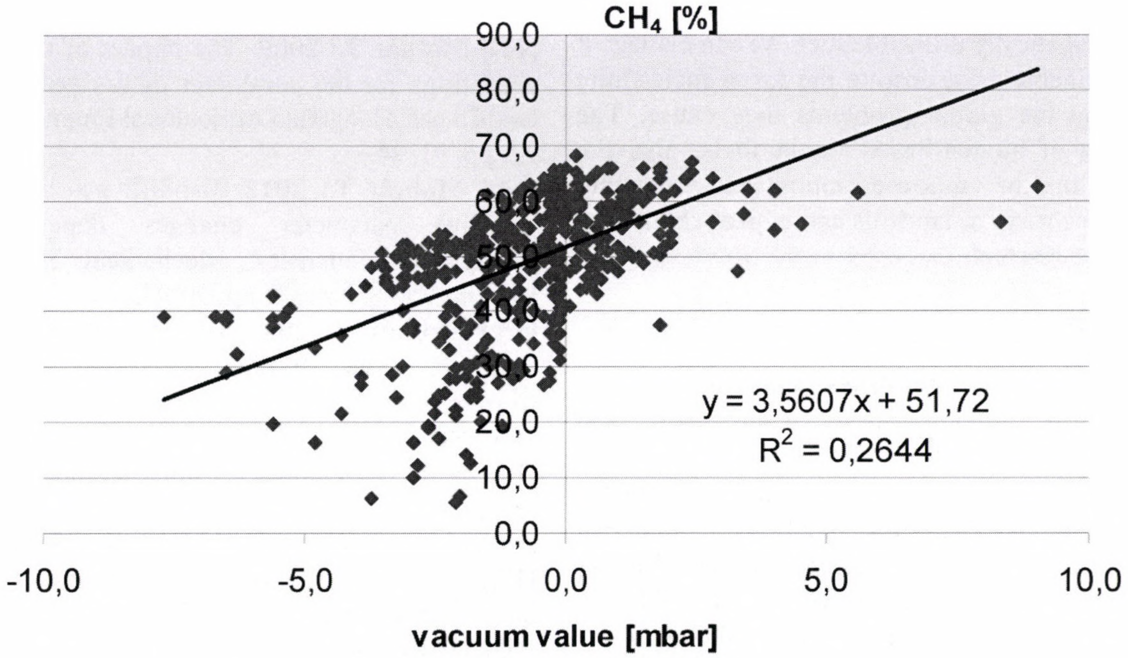

Figure 9. Changes of methane content in all gas wells in connection with volume of aspiration

5. Conclusion

Our three short-term tests were operated with commercial gasoline and two different bioethanol fuels (AGIP-E85, OIL-E85) and their blends with gasoline to compare the IC engine behaviours by unchanged settings. We'd recognised more less, than 50% values in case of torque and effective power, which can explain with lower calorific value (26,7MJ/kg) and stoichiometric ratio (8,97) of bioethanol fuels. We would like to continue our examinations testing the further percentage distribution of several blending bioethanol fuels. In accordance with literature the effective power and the torque grows as we decrease the bioethanol content in the fuels. [3, 4] Certainly by engine settings changes (e.g. ignition timing adjustment, increasing compression ratio, spark plug) we can further improved behaviour of our engine. We found that the operating parameters of the landfill gas extracting system used at the refuse dump has an effect on the changes of the methane content of the landfill gas. we determined the collection value according to the barometric pressure taking environmental pressure conditions into account. When the vacuum is higher than -0.9 mbar per gas well the methane content values significantly decrease. The relationship between vacuum values and the methane content of landfill gas shows r=0,52 coefficient of correlation which indicates moderate closeness of relationships.

The results of the bioethanol and landfill gas experiments show something interesting. From the agricultural sector's main products and the communal sector's waste, through biological means, we may obtain energetically utilizable fuel. We can manage it in a sustainable way, despite the fossil fuels finite nature and the global problems they cause. The utilization of biogen-based liquid fuels, also the increase in the mixture ratios and reducing Greenhouse gases at landfills cause great challenges and require research.

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Faculty of Mechanical Engineering

HYBRID SOLAR SYSTEM (PHOTOVOLTAIC/THERMAL) UTILIZATION FOR HOUSEHOLD APPLICATIONS

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Abstract

The aim of this study is to introduce the possibilities of using a hybrid photovoltaic/thermal solar system, tailored to a city located in southern Iraq - latitude 30.5°N and longitude 47.8°E. The reason is: to treat the electricity shortage problem by covering a certain share of the household needs. The study separates the system into two (solar thermal and solar photoelectric) systems, and while using it as a hybrid PV/T system, aims to find out the efficiency and production of both cases by using a water cooling technique. Where installed, the separate systems will cover 100% of hot water, and 39.5% electricity needs, while the hybrid system covers about 63.01% of hot water and about 44.34% electricity needs for the household.

Keywords

Hybrid photovoltaic/thermal system, Photovoltaics, Domestic hot water, Solar radiation.

1. Introduction

The total dependence on the use of fossilised fuels as a main energy source in all applications, the increase of oil prices, and the negative impacts on the environment - all these factors motivated many scientists to invent a system friendly to the environment. This system relies on natural resources, such as: the sun, sea waves, subterranean energy, wind energy, and others. Several analyses were conducted on hybrid PV/T system in theory, as well as the development of cogeneration components, like (PV/ thermal). In recent times, the PV/T solar energy utilization achieved a notable increase, due to the improvement in the performance of PV/T systems [1]. Said improvement consists of a combination of photovoltaic PV cells and solar thermal energy absorbing elements. The power generation is either thermal or electric using solar thermal collectors or PV panels, and there are many types of already advanced PV/T flat-panel collectors. Flat plate PV/T collectors can be split into various categories, according to the nature of the heat transport medium (air or water). [2] And they mainly consist of two systems (flat plate collector and PV system). It produces electricity by the use of solar cells and hot water, and exploits this energy in different house applications. The aim is to heat up the air instead of heating water, drying, or other purposes such as solar cooling, that depends on the sun as a main source to produce thermal energy. This system invaded the field of renewable energy, as it was found that the hybrid PV/T (photovoltaic/thermal) system can provide both electricity and heat at the same time. In order to maintain the electric efficiency of photovoltaic cells at an adequate level, it is necessary for the PV modules to operate at low temperatures. Natural or forced air circulation are simple and low-cost methods for transferring heat from the PV modules [3-4]. Conventional flat plate solar thermal collectors with PV cells that work by absorbing solar radiation, transforming it to the output of both electrical and thermal energy, have also removed the heat from PV cells. This lead to higher electrical efficiency of the photovoltaic part, and the useful thermal energy extracted from one end of the ducts can be exploited. [5] The potential for hybrid system applications is that they can generate both electricity and heat, which can be used to decrease greenhouse hot water usage.

The result of the production of electrical energy from the PV panel increasing is that it also increases the flow rate. This is attributed to the fact that the panel operates at lower temperatures. This indicates that the additional energy required from usefulness to cover the electrical and thermal loads is successive [6]. To take advantage of the hybrid solar collector, in order to maximize the contributions of solar energy to generating electricity and thermal profits, using a hybrid PV/T solar water collector as a single system is both efficient and dependable. This system includes thermal absorption and PV functions [7].

2. Methods

House characteristics

The house in question is located to the south of Iraq (Basrah city), with an area 150 m^2 and flat roof of 120 m^2. There is no shade that can cover the roof, like a tree or high building. And the surface level is not sloped. The roof of the house is made of concrete, the thickness of the roof is about 16 cm, and the wall's thickness is about 31 cm. The surface of this house is covered by pieces of gray cement called (stager), and the house is surrounded by a brick wall with a height of 1.5 m. The number of people living in the house is 4. The total annual electricity consumption in this house is 23 934 kWh and the amount of hot water the house needs 300 litres/day.

Meteorological condition in Basrah city

Basrah city has a semi-desert climate with high temperatures in the summer, where some days reach 56 °C. The mean temperature is 10 °C in the winter, where some days reach -1 °C. The mean temperature peak is 38 °C. The daily average wind speed ranges from 5 m/s to 9 m/s. Max humidity is 94.5% and min humidity 5.14%. [8] The readings taken from the national renewable energy lab (national solar radiation database) show the monthly average solar global horizontal irradiance data depending on the location of Basrah city for each month. The average annual was 5.45 kWh/m^2/day, where the maximum value of solar radiation was in June: 7.613 kWh/m^2/day. But this value will sharply decrease in December: 2.849 kWh/m^2/day [9].

Theory of solar utilization

Solar flat plate collector

This system works by the solar collector absorbing solar radiation, and converting it to heat, and the system taking advantage of said heat for heating water, after which it transfers this heat to a fluid, in order to be used by household applications, which reduces dependence on electric heating. [10] The energy absorbed into the collector comes partly from the radiation affecting the cover, which is absorbed and reflected, whereas the other part affects the glazing material, so not all solar radiation that affects the collector can be taken advantage of. In the end, only a fraction of that radiation is absorbed by the collector. [11] The net rate at which incoming solar energy is absorbed by a collector can be calculated as follows:

$$q_{solar} = G\, A_C\, (\tau\alpha)_e \qquad (1)$$

Where (G) represents all components of solar radiation

$$G = G_{direct} + G_{diffuse} + G_{reflect.} \qquad (2)$$

The net rate at which incoming solar energy is absorbed by a collector can be used to calculate heat loss as follows:

$$Q_{loss} = U_L\, A_C\, (T_b - T_a) \qquad (3)$$

The energy salvaged by a collector can also be determined by measuring the inlet and outlet collector temperatures, and the mass flow rate of the fluid coursing through the collector as follows:

$$Q_u = \dot{m} C_p\, (T_i - T_o) \qquad (4)$$

And the thermal efficiency of the flat plate collector can be calculated by using the following equation:

$$\eta_{th} = Q_u / GA_C \qquad (5)$$

PV Solar system

The recent accelerated growth of this kind of system is mainly due to better performance and the ability to cover either a part of, or all electric energy needs. The ability to convert sunlight into usable energy is affected by several factors, such as cells' temperature, the amount of radiation, and module design. The effective PV temperature (TPV)eff describes how temperature has a significant effect on system operation of PV, where rising heat leads to reduced efficiency of PV system [12]. The effective value (TPV)eff can be calculated by the following formula:

$$(T_{PV})_{eff} = T_{PV} + (T_{PV/T} - T_a) \qquad (6)$$

The conversion efficiency of a PV panel depends on the fluid temperatures – the fluid absorbs the high temperature from cells to keep the stability of conversion efficiency. [2] This can be calculated using the following equation:

$$\eta_{DC} = \eta_{DC0} \, [1+ \beta \, (25 - T_s)] \qquad (7)$$

And the efficiency of a solar photovoltaic cell is measured using the following equation:

$$\eta_e = I_m V_m / G \, A_c \qquad (8)$$

Hybrid PV/T solar collector

An increase in the PV cell's temperature leads to a drop of electricity conversion efficiency, because more than 80% of the solar radiation falling on the photovoltaic cells doesn't get converted to electricity, but is either reflected or converted to thermal energy. To counter this, usage of the hybrid PV/T system is a method, as it will provide electricity and hot water at the same time, and use the water as a cooler for solar cells. Therefore, it is necessary to operate the PV modules at low temperature to get better efficiency when the system operates [13]. The efficiency of the PV/T system is determined by the equation below.

$$\eta_{pv/t} = \eta_{th} + \eta_e \qquad (9)$$

Software used

More than one software program was used for calculations, for each system separately, in order to know the amount of output and efficiency of each system when operating separately, and to find out the results of them working as a single PV/T system. The main calculation for this system consists of three parts. The first part is the calculation of the solar thermal system separately (flat plate collector system) by using the (T*SOL Pro 5.5) software. This software has significant possibilities, it's flexible in calculations, and also provides accurate results. The second part's related to the photovoltaic system - the calculation of this system is done by the (Sunny design 3 software) program. This has possibilities to compute with different choices with different probabilities, modify or change parameters, and presents precise results with graphical interpretations. The third part represents the final calculations for the combined (flat plate collector and PV system), but as a single system (hybrid photovoltaic/thermal solar panels) this software also gave results for hybrid systems with exact values for amounts of hot water and electric production.

All the software that were used were not applicable to usage according to Basrah city, for these were selected for Baghdad city instead of Basrah. At longitude 44.7° E, latitude 33.1° N , where Baghdad is, the annual average solar radiation is 5.48 kWh/m²/day and the average temperature is 34 °C. While Basrah city is located at Longitude 47.8° E, Latitude 30.5° N, where the annual average solar radiation is 5.45 kWh/m²/day and the average temperature is 38 °C.

3. Calculations

Results of the calculations for the PT system

Common data for each program

Location: Region: Asia, Country: Iraq, city: Baghdad

Latitude: 33.1°N, longitude: 44.7°E, and the altitude above MSL is 33 m

Installation: Orientation: south, azimuth angle: 0°, and the tilt angle: 23°

Climate: Annual average solar radiation 5.48 kWh/m²/day, average outside temperature: 34°C,Low outside temperature: 7.8°C.

Part (1) flat plate collector calculations

Hot water consumption: Average daily consumption: 300 litres, and number of people: 4.

Usage of hot water over a year (bathing, cooking, sanitation and washing machine, others).

Collector array: Collector manufacturer: Baymaka. s. Baxi group.

1. Type: advanced XL, description: flat plate collector.
2. Cross surface area: 2.51m².
3. Active solar surface: 2.32 m².
4. Specific heat capacity: 3588 Ws/m²K.
5. Volume flow rate: 3 (l/h) /m² per collector area.
6. Insulation: Rock wool 40 mm.
7. Black plate: 0.8 mm aluminium.
8. Mixing: water-glycol 40% polypropylene glycol.
9. Distance between each collector: 1.09 m.
10. Number of collectors: 12.

Dual coil indirect hot water tank: Manufacture: standard, number of tanks: 1, volume: 1000 litres, Losses: 2.23 kWh/day, thermal loss rate: 2.99 W/K. Insulation of the tank: 100mm.

Boiler auxiliary heating: Manufacturing: standard, Boiler type: electric with nominal power: 2kW.

Table 1. DHW (domestic hot water) consumption, flat plate collector and collector loop

Average annual production	115.7051 m^3	**Total cross surface area**	116.12 m^2
Average daily production	317 litre	**Specific volume flow rate**	2.94 litre/h
Average DHW temperature	65 °C	**Specific heat capacity**	5900 Ws/m^2K
Annual energy requirement	6550 kWh	**Simple heat transfer coefficient (heat losses)**	4.36 W/m^2K
DHW heating energy supply (annual)	6217 kWh	**Heat capacity of mixture**	3533 Ws/kg K
Solar contribution to DHW (annual)	5.2 kWh	**Heat transfer medium with water**	40 % polypropylene glycol
Conversion factor	67 %	**The energy delivered by the collector loop (annual)**	5520 kWh

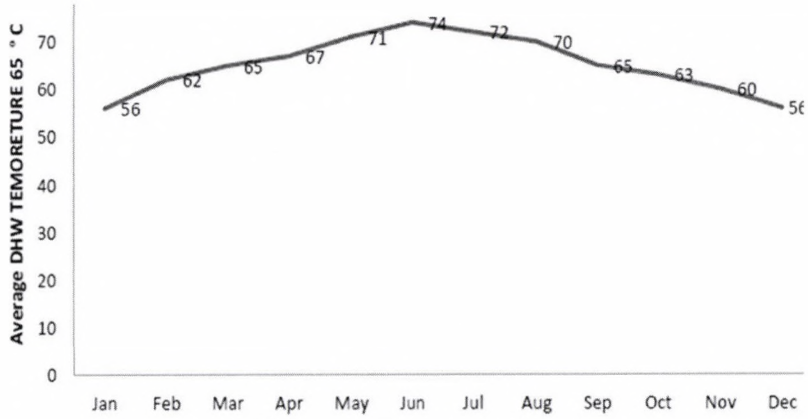

Figure 1. DHW temperature

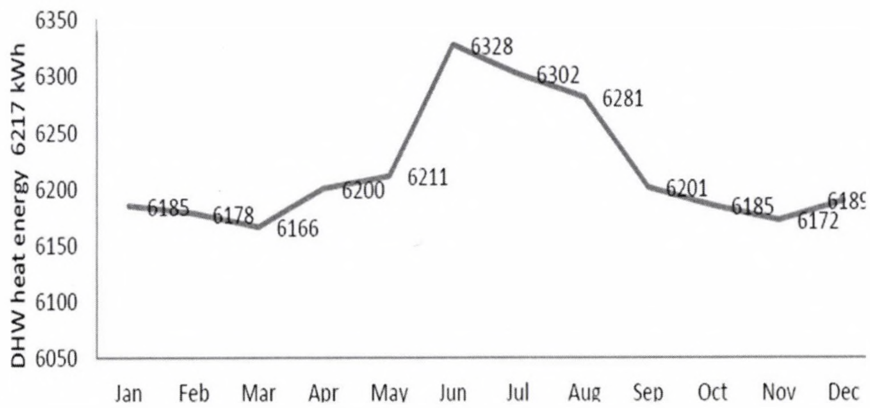

Figure 2. DHW heat energy supply

Table 2. Auxiliary heating and System performance

Auxiliary heating		**System performance**	
Type	Electric heater	**CO_2 Emission avoided**	1817.47 kg
Average Energy Auxiliary heating (annual)	58.4 kWh	**DHW solar fraction**	52.4 %
Efficiency	85 %	**System efficiency**	43.3 %
Energy from auxiliary heating (annual)	1710.8 kWh	**System yields**	5200 kWh
Efficiency based on the higher heating value	77.56 %	**Average annual production**	115.7051 m^3
Efficiency DHW supply	55 %	**With a return temperature of**	33°C

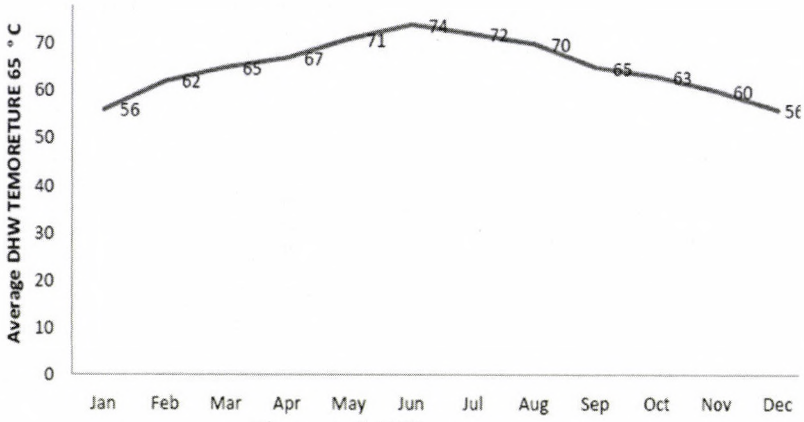

Figure 3. Total solar flat plate collector

Part (2) photovoltaic system calculations

Line losses: D Cand load: All Electric devices + heating +hot water.

Number of PV modules: 12, with manufacturers/ PV module: Shinsung Solar Energy Co. Ltd, PV module: TS-S 430 (UL). Cell Technology: Monocrystallin: it has the best power to size ratio and efficiency, performance in cooler conditions, 18% conversion efficiency, and loss of efficiency is lower at high temperatures, It's good for limited space, PV module efficiency (STC): 16.77%.

Inverter design: 1 x SB 6000TL-21PV system section 1, and Max DC power: 6.28 kW.

Table 3. PV design data

Input A: PV array 1: 8× Shinsung Solar Energy Co. Ltd TS-S 430 (UL), azimuth angle 0 °, tilt angle 23 °
Input B: PV array 2: 4× Shinsung Solar Energy Co. Ltd TS-S 430 (UL), azimuth angle 0 °, tilt angle 23 °

	Input A	Input B
Number of strings	1	1
PV modules per string	8	4
Peak power	3.44 kWh	1.72 kWh
Topical PV voltage	361 V	181 V
Min PV voltage	310 V	155 V
Min DC voltage (grid voltage 220 V)	125 V	125 V
Max PV voltage	525 V	263 V
Mix DC voltage	600 V	600 V
Max current of PV array	8.4 A	8.4 A
Max DC current	15 A	15 A

Table 4. The entire system's data

Photovoltaic design data Grid voltage: 220V (110V/220V) 50Hz			
Total number of PV modules	12	Performance ratio	72.4%
Peak power	5.16kW	Specific energy yield	1833 kWh/kWp
Number of inverters	1	Unbalance load	6.00 KVA
Nominal AC power of the PV inverter	6.00 kW	Max. AC active power (cos ϕ=1)	6.00 kW
AC active power	6.00 kW	Self-consumption	6546.65 kWh
Max. DC power (cos ϕ=1)	6.23 kW	Self-consumption quota	69.2%
Annual energy yield*	9460 kWh	Self-sufficient quota (energy consumption in %)	27.4%

Results of the calculations of the PV system

Part (3) Calculation hybrid photovoltaic/thermal solar panel

In this part, the calculations will be conducted for a hybrid system (PV/T) and the software will depend on previous parameters which used it when the systems were evaluated separately, and there are other parameters used with the Polysun software as well, like auxiliary heating: Electric, Storage tank: multi Val CRR 1.25 m, temperature control: class VI-weather compensator, room senior for use modulating heater and pump collector: Small pump.**Results and Conclusions**

According to data that was used in part (flat plate collector) and part (photovoltaic system), and other input data that were used in part three of calculations, the data gained from this part referenced the hybrid system results to a single system (photovoltaic/thermal system), and the results gained from PV/T system were diverse. If we make a comparison between the results of the systems when they were handled separately (FPC+PV system) and the results of the combined PV/T system, looking at the hot water production of the singular system, we get a result of 317 litres/day, and the annual hot water production was 115.7051 m3. The specific volume flow rate was 2.94 l/h, and the average DHW temperature was 65 °C with a 43.3% efficiency for system. As seen in Tables 1 and 2, while hot water production for the hybrid system is 200 litres/day, and the annual production was 73 m^3 and specific volume flow rate was 1.85 l/h, the water temperature output from the hybrid system was 51 °C. The hot water decreased when the system was handled as a single system, because the hot water production came from the absorption of the high temperatures generated by the solar cells, due to direct exposure to solar radiation. Temperatures differed because the piping that carried the water was not directly exposed to solar radiation, and temperatures at the location of piping were below that of the solar cells', so the water worked as s cooling system for solar cell, That is why the amount of hot water production was decreased by 36.91%. When used, the amount of hot water procured from the hybrid system covered about 63.01% of the household's needs, which is considered appropriate for household applications. And in comparison, the electricity produced when the system was a single PV system was 5.16 kWh.

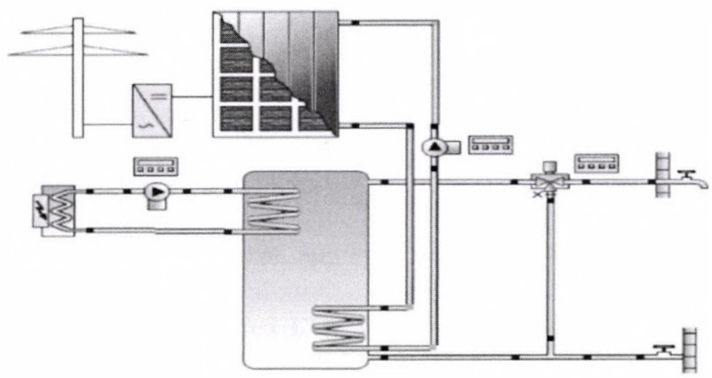

Figure 4. Design of the PV/ T system

Table 5. Production of photovoltaic/thermal hybrid system

Total gross area	116.7 m²	Annual energy production of PV (AC)	10611 kWh
Total annual field yield (solar thermal energy)	5355 kWh	Inverter	SB 6000TL- 21
Collector field yields related to gross area	672.8 kWh/m²/yr	CO_2 savings	1821.2 kg
Collector field yields related to aperture area	672.8 kWh/m²/yr	Total solar fraction	52%
Annual solar thermal energy related to the system [Qsol]	446.34 kWh	Performance ratio	76.8%
Average reduction in CO_2 emission	4357.55 kg	Total efficiency	58.6%
Photovoltaic roof plan 1	Monocrystallin	Life span (PV/T system)	25 years
Total nominal power generation field (peak power)	6.42 kWh	Specific energy yield	2343.3k Wh/kWp

Table 6. Results of component systems

Hot water demand		Circuit pressure drop [pump]	0.193 bar
Volume withdrawal/daily consumption	200 litres/day	Electricity energy consumption (annual)	23.5 kWh
Annual hot water consumption	73 m^3	CO_2 savings solar thermal	2561.4 kg
Average temperature of water out of collector	51 °C	Storage tank	
Specific volume flow rate	1.85 l/h	Volume	1000 L
Energy demand [Qdem]	2616.8 kWh	Height	1.25 m
Boiler and Pump collector			
Circuit pressure drop [boiler]	0.34 bars	Thickness of insulation	110 mm
Total efficiency [boiler]	87.2%	Heat loss	278.2 kWh
Auxiliary heater Electric [boiler Power] annual	36 kWh	Connection losses	126.7 kWh

The peak power, and the annual electricity production of the system was 9461 kWh, with a system performance ratio of 72.4%, as seen in Table 4. While used, a hybrid PV/T system gave about 6.42 kWh peak power, and the annual electricity production for the system was 10611 kWh, with performance ratio 76.8% as seen in Table 5. There is an increase in the amount of electricity produced when using the hybrid system - about 1150 kWh, or 10.83%. And the performance ratio increased by 5.73% when using the water as a cooling system for solar cells. The amount of electricity produced from the hybrid system covered about 44.34% from what the household needed. The total efficiency of the hybrid (photovoltaic/thermal) system was 58.6%.

Abbreviations

q_{solar}: rate of energy loss from the collector (kW)
$\dot{m}$: mass flow rate (kg/s)
G: incident total radiation on a collector surface (kWh/m²)
T_i: inlet temperature °C
A_C: collector absorber area (m²)
T_o: outlet temperature °C
$(\tau\alpha)e$: effective transmittance-absorption production
T_{PV}: PV module temperature °C
Q loss: heat losses from the collector (kW)
T_a: ambient temperature °C
U_L : overall heat loss coefficient W/(m²K)
η_{DC}: conversion efficiency
η_{DC0}: reference conversion efficiency (cell temperature 25 °C, reference solar radiation 1000W/m²)
T_a: air temperature in the vicinity of collector °C
T_s: cell temperature °C
T_p: the average absorber temperature °C
Q_u: the rate of useful energy extracted by the collector (kWh)
β: temperature coefficient of solar cell efficiency (1/K)
I_m,V_m: current and the voltage of the PV module operating at a maximum power (A, W)
$T_{PV/T}$: operating temperature of PV/T module (°C)
T_{PV}(eff): effective PV module temperature °C

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Faculty of Mechanical Engineering

EVALUATING SYSTEM DEVELOPMENT OPTIONS IN CIRCULAR ECONOMIES FOR THE MILK SECTOR - DEVELOPMENT OPTIONS FOR PRODUCTION SYSTEMS IN THE NETHERLANDS AND HUNGARY

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Abstract

The currently operating economic structures all follow the perspective of linear economies, which roughly translates to "produce - manufacture - discard". This, however, doesn't support the perspectives of the actual sustainability of natural resources, the operation of material circulation, or the planning of synergy between systems. In this research, we used a dairy farm in the Netherlands as an example to evaluate mainly the methods of moving from linear economic systems towards circular systems, for the sake of sustainability. Based on the analysis of three models from the Netherlands, we designed an analysis method that can help domestic entrepreneurships select strategies which help the actors of the dairy product sector move from linear economic systems towards circular ones. During the analyses, we mainly used the relevant data of LPT Ltd. (Livestock Performance Testing Ltd.) as the database. We requested professionals for consultations in order to receive the mandatory professional estimate. Furthermore, we cross-referenced the fundamental parameters of domestic systems using benchmarking. In order to create an understandable overview and actual strategy from all this, which can also be used in practice, we determined a division logic that's applicable to three-unit life cycle phases. We also designed the so-called CEV (Circular Economic Value), which can be used to strategically plan the process of reconfiguring milk production strategies (1. Low-input/low-output; 2. High-input/high-output; 3. Low-input/high-output) to be circular.

Keywords

Circular Economy, Dairy production, Circular Economic Value, Life cycle assessment

1. Introduction

Nowadays, sustainable and climate-friendly production gets a more and more important role in our daily lives. The need for methods aiding possible environmental, climate-related, social and economic problems that may appear related to manufactured and consumed products is also more important - due to them aiming to prevent negative influences these systems may have. The life cycle assessment and the circular economic model can be used together, which provides an opportunity to evaluate the criteria of long-term sustainability in our current economy, on multiple levels. The life cycle assessment process explores the environmental factors and potential environmental effects, which lets us analyse products and services 'from the cradle to the grave'. The life cycle assessment describes the entire lifespan of products and services. Among the areas to which the analysis is applicable, we can also find the usage of resources, and effects which are hazardous to human health and the balance of ecologies [1]. LCA models the life cycle of the product, for the entire product system. The product system has the fundamental attribute of being determined functionally, and not merely from the perspective of the end product. In the case of our current analysis, designing a B2B (business to business) -type life cycle system structure

became mandatory. This simplified life cycle system is used for procured base materials, which mainly consists of the following parts (Figure 1):
–input material manufacturing
–production process
–distribution process

Figure 1. B2B-type life cycle model

Both the climate change and the processes, which are increasingly hard to be sustained, place current politicians and decision makers into a tight spot. Nowadays, actually interpreting the problems of climate change also became a daily occurrence for average people, who start to feel the importance of handling them. Therefore – even for ordinary people - the need for taking the criteria of sustainability into consideration is steadily becoming more apparent, similarly to the initiative to deepen related knowledge. This can be achieved by using the life cycle assessment analyses together with the newest sustainability concept, named the "circular economy" model, for any relevant areas of daily life. 'Sustainability' and 'sustainable development' may be some of the most notable concepts in the XXI. Century. The Environment- and Development World Council of the UN issued the 'Our Common Future' report in 1987, and its contents reach more and more people nowadays. It says "Sustainable development is a kind of development which can assure that our current needs are satisfied, without endangering the opportunities of future generations by satisfying its own needs." [2]. If we want to form a deeper understanding of the definition, we have to interpret it in a complex fashion, since it encompasses multiple factors.

The most notable are the social, environmental and economic dimensions, the equilibrium of which can be called the basis of sustainability. These three dimensions are called the 'pillars of sustainability' (Figure 2).

Figure 2. Pillars of sustainability [3]

Sustainability is basically a state supported by these three pillars, and in case a change occurs in one of the factors, the other two will also experience change. The three-way optimisation between these pillars is important for establishing long-term sustainability [4].

Possibilities for transformation - the circular economy model

The currently operating economic structures follow the principles of the linear economy, which basically means 'procure – manufacture - consume – discard', or ' produce – manufacture – discard' in short. This, however, doesn't support the perspectives of the actual sustainability of resources, the operation of material circulation. Linear economy is based on linear processes, which prefer large mass products and cheap production costs. It mostly supports itself by procuring the necessary base materials for relatively low costs [5, 6].

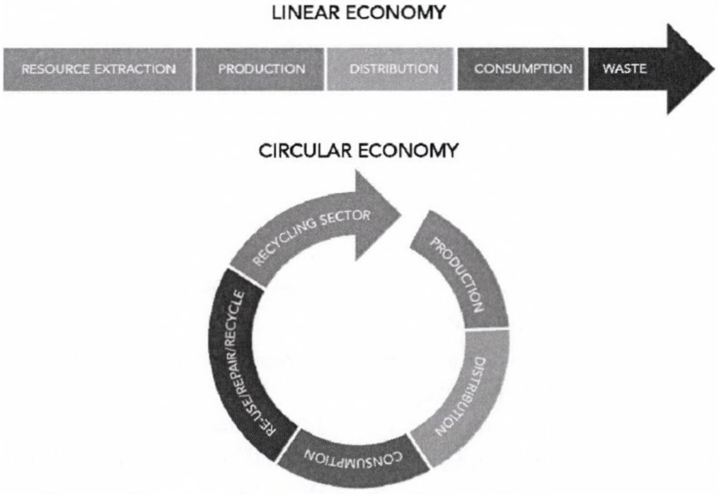

Figure 3. Basic structure comparison between linear and circular economic systems [7]

The circular economy can recycle manufactured products at the end of their life cycles, resulting in minimal, or no waste, using minimal, or no resources. The main processes of circular systems are the complete reduction, recycling, reuse, re-manufacture and improvement of waste. The circular economic model is basically an industrial system, where the 'end-of-life' concept is discarded in favour of repairing, and the usage of renewable energy sources is advised and promoted. It tries to eliminate waste by expert designing of materials, products, and systems – most notably business models [8, 9]. Circular systems introduce – and elevate – another aspect, which had its influence diminish gradually in western manufacture systems during the second half of the XX. Century, which is prevention.

The logic of the new circular approach accepts that even though circulating waste within the system is inevitable, the solution it offers for the fundamental problem is at best, slightly effective. During the second half of the 1900s, a new branch of the linear economy approach was spread - this was the manufacturing of products with life cycles cut short. This basically meant shortening the usage lifetime of products artificially - during the production process [10]. The definition of 'planned obsolescence' can be attributed to the first few years of the 1930s. This is when an American economist first mentioned the possibility of its usage, which would offer a solution for the great economic depression of that time. Though it wasn't adapted widely at the time, 20 years later, it can be said that it was widespread practice within production systems [11]. This perspective still helps in sustaining the consumer society based on over-production to this day.

However, even decision makers managed to understand how the management of waste resulting from these processes cause an increased deadweight, which is more than their gains extracted from the economic growth, which happens due to the aforementioned processes. This is why the circular economy tries not only spreading the approach of reusing waste as a new form of capital, but also takes measures to lengthen the life cycle at the beginning of the process. This may be solved by modifying the warranty systems in a way that is applicable to a thought process tailored for long life cycle products. It further promotes designing business models (sharing economy, refurbishing, re-manufacturing, upcycling, etc.) which push actors taking part in manufacturing or distribution to make and promote products with as long lifespan as possible.

2. Method of Analysis

Due to the complexity of the topic, and the time constraints and variety in data at hand, which is applicable to the analysis, we chose the benchmarking method for conducting our evaluation. Benchmarking is a level-comparison method, which can be used to make a state for a set time and space comparable to another, by adhering to a set criteria system [12]. The benchmarking method can be used to compare even an entire sector for a set time and space, along the criteria system. We can use a mechanism with it, which assesses a future state based on the criteria system designed for the present condition. The reason for choosing the methodology is that benchmarking can be customised and specified for the analysis goals [13]. During the analysis, we used a simplified benchmarking to describe the milk production systems of the Netherlands, after which we designed a provisional framework system for evaluating domestic systems, in order to set a basis for future benchmarking analyses.

3. Results

The European Union abolished the 30-years old quota system for the milk market regulation in 2015. According to mid-term estimates, this increased the intensity of the competition for the milk market, which further caused a structural reconfiguration in the sector after a while. This process is assumed to cause a notable share of base material procurement to shift towards cost-effective manufacturing areas, which will in turn make the rationalisation of manufacturing base materials indispensable. Restructuring the domestic sector will be mandatory, which can be efficiently supported by an example already in effect in the Netherlands, based on the fundamentals of 'circular economy' - optimised for the domestic criteria system, of course. In our current analysis, we construct a guideline according to the example from the Netherlands, based on the circular economy model - in other words, the methodological solution blending the life cycle assessment and benchmarking methods. Our guideline can help achieving an optimal equilibrium in production systems via the 'Circular Economic Value', abbreviated CEV.

Analysis of models in the Netherlands

The basis of our analysis was the Dutch example modelling the transition towards a circular economy. We tried to apply this to our domestic criteria during the first steps as well. In the Dutch model, three types of milk production systems were differentiated. These were applied to the criteria system and conditions of the circular economy.

Description of the Dutch practice's OPTIMISED (1) – EXTENSIVE (2) – INTENSIVE (3) graze farming and milk production:

1. *Optimised husbandry:* the technology aims at maximising production, matching biological goals to technological opportunities, thereby achieving circularity. This form of husbandry is the most widespread in Dutch milk production, but it has a significant development requirement in order to reach circularity.
2. *Extensive husbandry:* based on ecological or bio-farming, strictly prefers the soil- , plant- and animal-cycles, and local production. This system is closest to reaching total circularity, but it requires controlling and regulatory interventions. A financial return model has to be designed for it. It's not sustainable without subsidies from the State.
3. *Intensive high-tech husbandry:* in this solution, we can find both the basic principles of circular economy, and modern technological solutions. The system is already circular for the key areas, and also has advantages for productivity and circularity. However, from the perspectives of adaptation and social acceptance, it still poses significant risks. Due to the large volume of output, linear systems have a notable role in operating it.

Operations of linear economic systems in milk production

In the case of the linear systems still in operation in the Dutch economy, production inputs are often used in a way that offers maximum income. Based on the law of diminishing returns, in the case of these production strategies, the increase in return by unit of production decreases, whereas the volume of environmental load related to excess production increases exponentially. The costs of neutralising appearing environmental externalities also increase. In practice, this results in negative effects related to the milk cycle appearing en masse, while we can observe nutrients getting washed out of the soil or leaking out, the emission of greenhouse gases (NO_x, CH_4, CO_2) increasing, and the water bodies being over-polluted and overused. In the case of linear systems, market connections usually aren't based on cooperation, which causes global market exposition, hectic changes in prices, and fundamentally erratic changes in conditions related to manufacturing and consuming safe products (changes in feed prices, diseases, epidemics, climate effects). General income security is also under constant duress. In the case of linear production systems, milk yields may be excessively high, but will also cause the pollution and emission related to production (by-products, waste, GHGs, nitrogen and nutrient washout) to skyrocket (Figure 4).

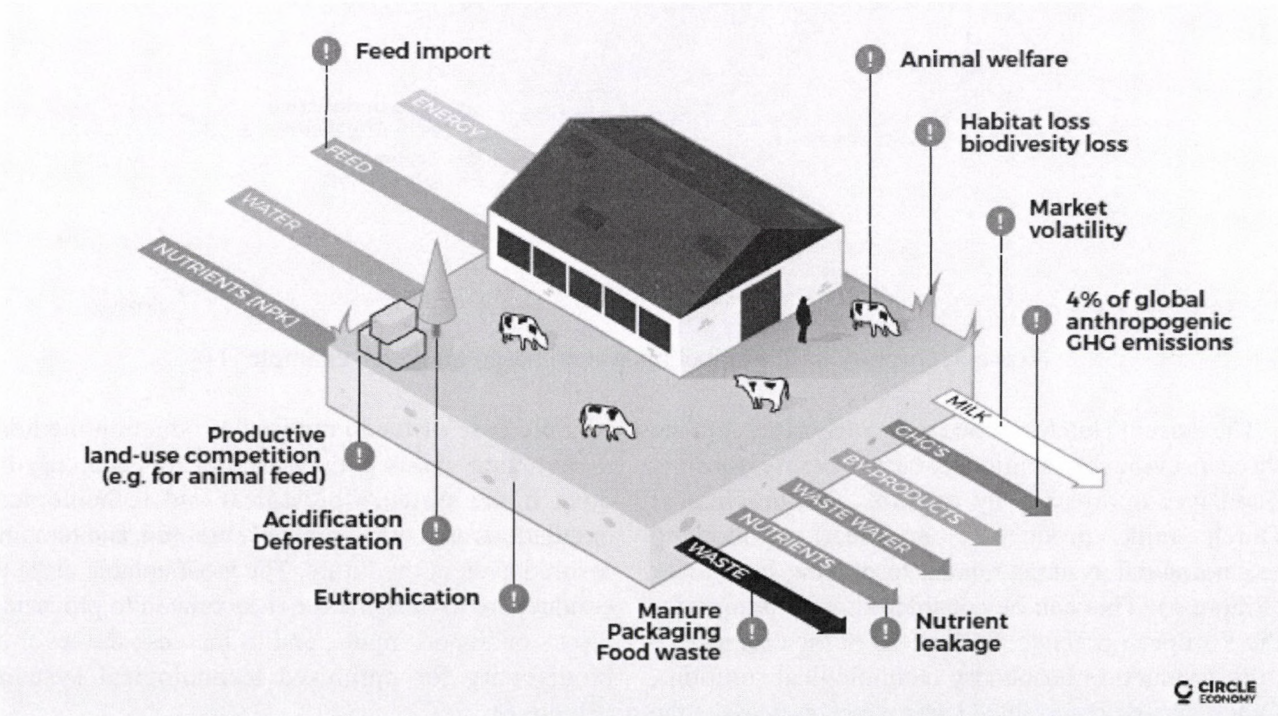

Figure 4. Linear milk production system based on the Dutch example [14]

Transforming linear systems to circular systems in practice in the Netherlands

Circular milk production systems concentrate on realising closing cycles, which mean new challenges mainly during the operation and the usage of natural resources (Figure 5). By decreasing environmentally problematic effects, they wish to achieve positive effects from the perspective of regenerating rural areas and ecosystems [14].

In the Netherlands, greenhouse gas emission rates, realising nutrient cycles and increasing bio-diversity are the areas which can be considered key factors for improving the conditions of sustainability. We can safely state that thanks to the general environmental awareness of the farmers, neither soil- or rural conservation, nor the questions of water and waste management pose a problem.

As for the Dutch production systems, the transition towards a circular economy poses significantly less demands than f. e. the milk production systems of post-socialist countries, including Hungary. Dutch farms' soil nutrient supply, waste management, water usage and sewage treatment, soil quality conservation, and general quality conservation technological solutions are already widespread in practice, on a professional level. In the case of animal feeds and fertilisers, they successfully achieved a state where usage of different materials effects on water and air quality are as insignificant as possible, while soil quality is kept maximised to the greatest possible extent.

The quantity of waste from milk producing dairy farms can be called nearly non-existent, or absolute minimal in current practice (Figure 5).

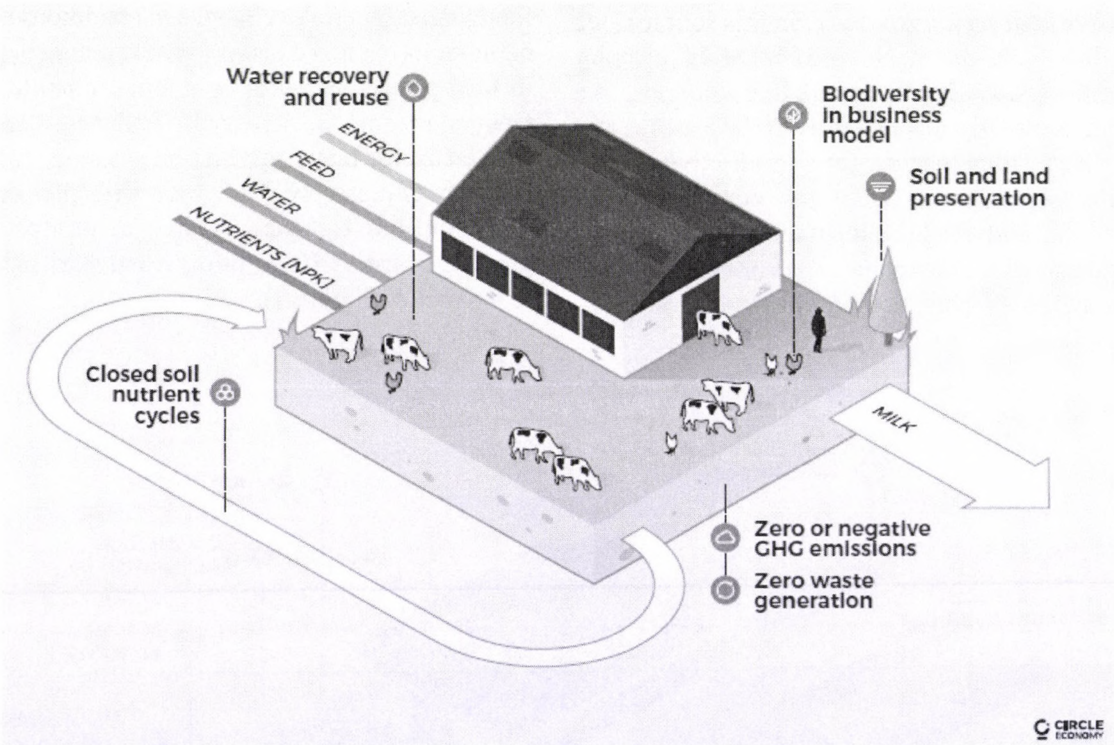

Figure 5. Circular milk production system based on Dutch example [14]

The current Dutch practice was categorised into the three previously mentioned categories (extensive, intensive, optimised) by experts. The practice of Dutch milk production is clearly following technological systems related to grazing husbandry (Figure 6). This can be considered quite unique for the European practice. In the case of the categorised milk production husbandry technological solutions, Dutch experts determined tasks which may assist the transition towards a circular economy within the various categories [14].

In the case of the 'optimised' production method, maximising yields is the goal, but this can only be done if the system's biological and technological circulations are both completely assured, and remains assured even in the future. The most notable tasks to conduct are to mitigate the risks related to procuring inputs or import inputs, and to increase the level of biodiversity for optimised technological systems (Figure 6).

The usage of the 'extensive' technology is the closest to achieving the optimum state of circular economy's system attributes, as it generates no negative externalities during its operations. However, it's often observed that it generates excess positive externalities, by which the system is also categorised with those that produce unsustainable system attributes en masse. The technology of extensive grazing isn't sustainable in the Netherlands either, meaning it shouldn't be continued with circular economy's system developments as a business model.

In the case of 'intensive' grazing technological system, we can mainly say that it can be operated using very expensive technological solutions, which is why a reasonable return timeframe can only be achieved with a significant income. Making sure that feed circulates, in other words, closing the cycle, is impossible with such a high material flow rate. This intensive process poses a huge challenge of both GHG emission, both water circulation to achieving a circular system.

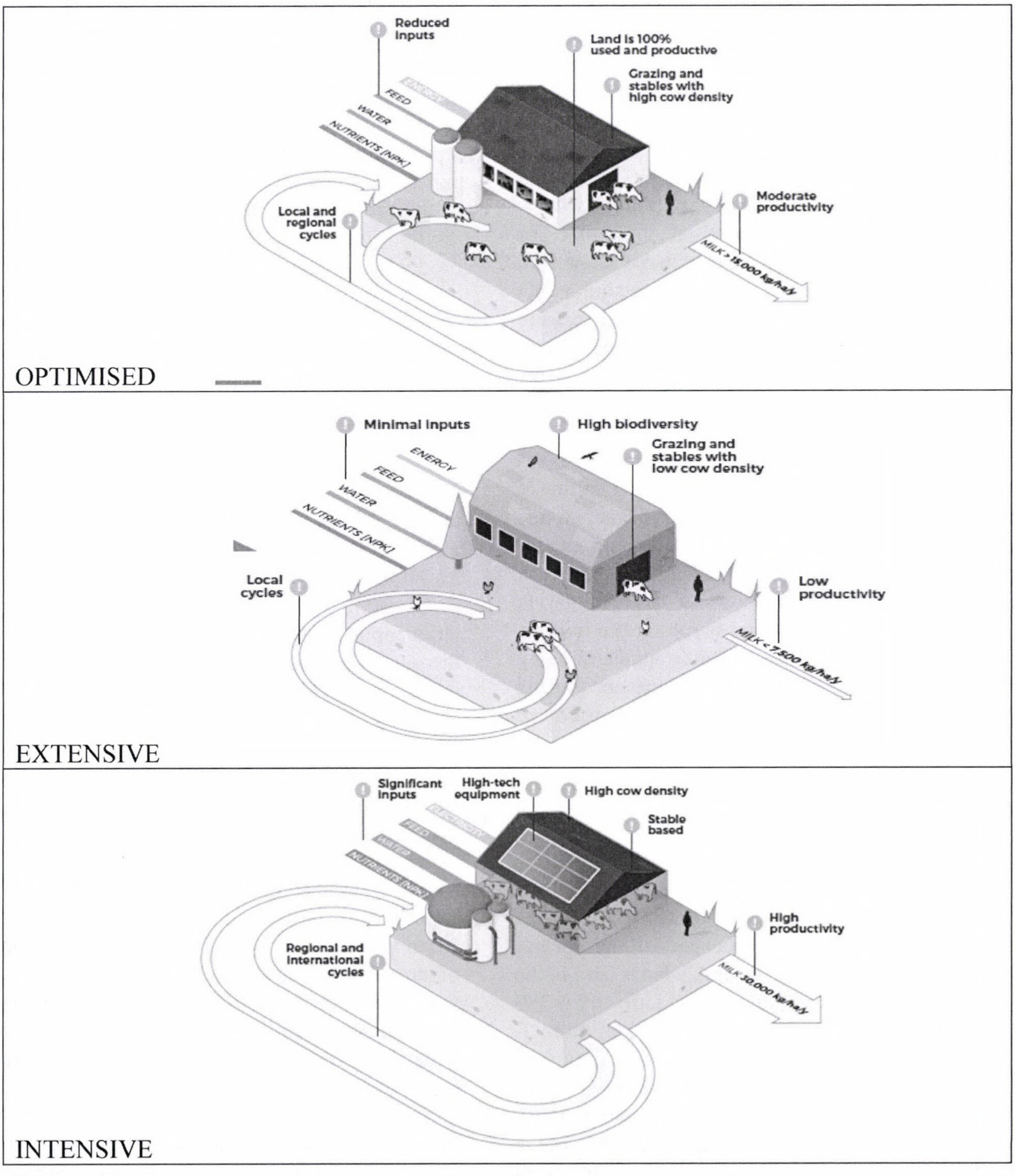

Figure 6. Husbandry methods currently in use in Dutch practice [14]

Circularity of linear milk production systems in Hungarian practice

The main goal of our research was to categorise the domestic milk production technological solutions, based on Dutch examples. We also tried to pave a way for domestic dairy farms towards circular economic developments based on the categories. Based on the statistical data on hand, we weren't able to determine similar economic categories calculated for the Dutch system's indicators. The reason is that these can only be categorised with incomes that come from a wide spectrum, based on available statistical data, and are ill-suited for being the basis of universal structural attributes. Based on prior analyses, we understood that we often couldn't describe production plants related to the various categories, because the comparison conducted by using statistical data at hand didn't result in acceptable significance values. In practice, this meant that f. e. their size, or technological solutions used may have suggested prior the analysis that the dairy farms are similar, yet their income efficiency or yield indicators were completely different. This means that there was no chance of handling them as elements of the same group, or interpreting them as similar existences. The subsidy systems of domestic husbandry, and related development obligations (f. e. manure management) are varied. Feeding traditions are old, and adhering to the EU's regulations is mandatory. These factors determine an entirely different development route for the domestic sector, compared to the Dutch practice. In the following part, we show the Hungarian production models, which are based on the milking house production structure, and are capable of being landmarks for a strategic development taking circularity into consideration, which can be followed by other dairy farms.

Introduction of Hungarian base models

1. Low input – low output (extensive): This economic model is ecological from its holistic perspective, aims to reach long-term sustainability, but differs from the Dutch system because of the special forage production based on arable lands (due to the herd size). In Hungary, the average farm size is 380 milking cows/farm [15]. The soil-plant-animal-manure-soil is the model closest to complete circularity. Its basis is the production of own forage and protein on arable lands (home-grown protein), and the feeding model based on min. 70% forage ratio (based on dry matter) in the top lactation period. The quality of the home-grown forage can be medium (Net Energy for lactation (NEl) 5,5 MJ/kg dry matter). The production volume in this economic model is min. 8,000 kg milk/cow (for 305 days). Sustainability (including economic sustainability) is based on the cow producing close to 32,000 kg milk during its lifetime [16], meaning one of the most notable attributes of the 'low-output' model is the long productive life [17]. This is due to the cow reaching its production peak by the time of the third-fourth lactation period [18]. The feeding based on forage makes it possible to achieve 4 closed lactations on average [19]. Currently, the average lactation (productive life) is 2.2 in Hungary [15], which shows a similar value in the USA (2,63) [20]. Therefore, the returns achievable from the 'low output' system are long-term, since the long lifespan (return can be expected by reaching the potential peak production in the 3rd lactation, and the cost-optimised calf /heifer growing). By minimising purchased products, it's cost-efficient, but produces limited output. It's eligible for subsidisation from an animal welfare and animal health perspective, requires small investment to realise as an economic model, and is sustainable long-term. The risks related to inputs and import inputs are the lowest in this system, operations are only slightly dependent on market changes. Main indicators are: imported input feed and total feeding costs aren't above 25%; average productive life is at least 4 closed lactations; lifetime milk production is min. 32,000 kg milk for each cow.

2. High input – high output (intensive): as for its theoretic basis, this economic model is the most popular one in Hungary. In the current state of the economy (many bank loans due to recent farm reconstructions), the goal is to maximise the output. From the perspective of circularity, it's not an optimal model where increasing biodiversity is concerned. This is due to the limited opportunities to decrease the import input side, but on the whole, it's still a sustainable economic system. The model's exposure is significant, and can be instable due to social acceptance as well. Due to the huge volume of production, linearity plays an active role in maintaining the system. We have to add, though, that its theoretical basis makes this system the most widespread in Hungary, yet, where yield volume (output) is limited, Hungary's reality lags behind the goals we want to reach. This is mainly caused by management reasons. The basis of the high input model is feeding based on max. 50% concentrate in the peak lactation period (min. 50% forage ratio

based on dry matter), with an average forage quality. The production volume in this economic model needs to be at least 11,000 kg milk/cow (for 305 days) in the future. They reach this level of production via maximising the concentrate ratio. By improving forage quality, the concentrate ratio can be decreased of course, but the level of production makes it impossible to reach a forage ratio above 60%. This is the reason why this production system is a special type among the others. We can make it more sustainable, or more circulatory, if at least 50% of the concentrate costs will be produced by the dairy farm - adhering to the home-grown example. In the current practice, purchased grain- and supplements are 70-80% of total concentrate costs on average, and at least 45% of total feed costs. By trying to achieve a goal of 33,000 kg milk as lifetime performance for each cow, the system can become sustainable, if the productive life reaches 3 closed lactations using this feeding system. Reaching this indicator value requires long-term development work, well-executed implementation, and perfect dairy farm management. However, designating it as a goal is a must, since nearly all economic models' minimum requirements are to make the producing cow to reach the potential peak lactation and to cover the costs of both raising and production during its productive life. Main indicators are: imported input feed in total feed costs aren't above 40%; average productive life is at least 3 closed lactations; lifetime performance is min. 33,000 kg milk for each cow. It's important to note that in this farm system, the animal health treatment costs may be high, just as the costs related to early culling and animal deaths.

3. Low input - high output (optimised): In this economic model, the goal is to maximise output incomes, in a way that the system's biological and technological circularity is also sustained as best as possible. The basis of the low-input soil-plant-animal-manure-soil circularity model is the home-made 'excellent' forage based on plant production on arable lands (at least 6 MJ/kg DM net energy content for lactation, and min. 60% fibre digestibility), the high ratio of home-grown protein, and the feeding model based on min. 60% forage ratio (based on dry matter) in the peak lactation period. The production volume in this economic model is min. 9,500 kg milk/cow (for 305 days). This production level can be achieved in case if the (non-maize based) forage average net energy content reaches an average of 6 MJ/kg DM NEl value, the dairy farm produces top quality forages, and the TMR (total mixed ration) NDF-digestibility is close to 60%. If they reach for the goal of 33,250 kg/cow as lifetime performance, it's realistic to require the productive life to reach up to 3.5 closed lactations with this feeding system. Main indicators are: imported input feed in total feeding costs aren't above 30%; average productive life is at least 3.5 closed lactations; lifetime performance is min. 33,250 kg milk for each cow.

The data seen in the economic models are our own calculations, which are based on the national database of the Lifestock Performance Testing Ltd [15].

The main characteristics of the three milk production systems were summarised in Table 1. We have to mention that during the description of the models, we didn't aim to introduce all production or farming types. Instead, we wished to introduce systems which fundamentally determine domestic milk production's (mainly entrepreneurships dealing in milking house production) development possibilities, to offer a way to reach a sustainable dairy farm. One significant difference is that the method of producing eco- or bio-milk in Hungarian and Dutch practices is different. In the Netherlands, bio-products are exclusive to grazing sources, whereas in Hungary, these products are also mainly sold to customers by sources producing based on farming plant-based feeds.

Using the life cycle assessment and the benchmarking methods together to analyse circularity

In order to determine some kind of road towards the circular economy of the Dutch practice for the domestic production, we realised that including the specifics of resource usage, market, and social indicators that are characteristic of the given economic unit into the analysis. These factors are also applicable to the toolsets usable to intensify circulation level.

Due to the novel, holistic approach, the parameters of circularity can be determined for either the given product or the system in its entirety, and excavating the system insufficiencies causing non-sustainability becomes possible. Therefore, to describe milk production processes, we designed a theoretical model, which analyses the entire life cycle, but remains able to handle various phases based on their homogeneity (Figure 7).

Table 1. Analysis of the three technologies as Hungarian models

INDICATOR		LOW INPUT – LOW OUTPUT (EXTENSIVE)	HIGH INPUT – HIGH OUTPUT (INTENSIVE)	LOW INPUT – HIGH OUTPUT (OPTIMISED)
ASPECTS OF CIRCULARITY	Circulation of nutrients (✓-lowest)	✓✓✓	✓	✓✓
	GHG emission/kg milk (for in-stomach processes, ✓- lowest)	✓✓✓	✓	✓✓
	Bio-diversity (✓-lowest) for farmland plant production	✓✓✓	✓	✓✓
	Culling rate, mortality (✓-lowest)	✓	✓✓✓	✓✓
	Transportation of material flows, input-output ratio (efficiency of material usage) (✓-lowest)	✓✓	✓	✓✓✓
SOCIAL ACCEPTANCE	Acceptance (✓-lowest)	✓✓✓	✓	✓✓
PRODUCTION	Milk production (for 305 days)	min. 8000 kg/cow	min. 11.000 kg/ cow	min. 9000 kg/ cow
	Milking average	min. 25 kg/day/ cow	min. 35 kg/ day/ cow	min. 30 kg/ day/ cow
	Productive life (average number of closed lactations)	min. 4	min. 3	min. 3.5
	Lifetime performance (milk kg/cow)	min. 32,000 kg/ cow	min. 33,000 kg/ cow	min. 33,250kg/ cow
	TMR: forage ratio in the period of peak production	min. 70%	min. 50%	min. 60%
	Forage quality	average	average	exceptional (6 MJ/kg DM. NEl) and min. 60% TMR NDFd
	Home grown feed / all feed	min. 80 %	min. 50%	min. 60 %
	Import input feed costs	max. 25%	max. 40%	max. 30%

Source: self-made, based on the database of Lifestock Performance Testing Ltd. [15]

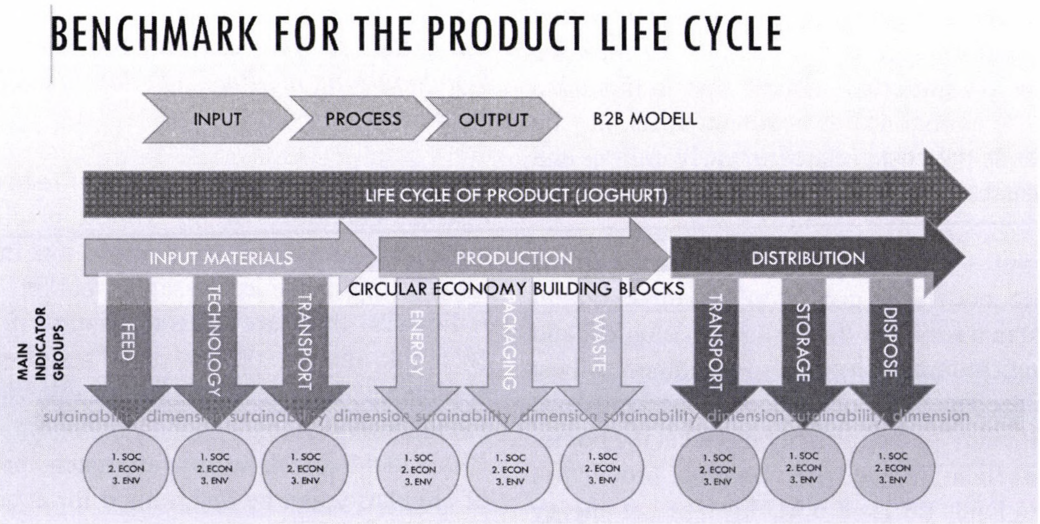

Figure 7. Possible life cycle of foodstuffs related to milk production

Life cycle assessment can be used well for milk production systems, and can also be applied to milk production practice safely. The level of adherence to circular systems can be assessed based on the LCA phases (Base materials - production - distribution), and by using the main- and sub-group indicators of the various phases (Figure 7). Determining the main indicators was done based on experts' decisions, and was arranged around three main production elements. Furthermore, the main indicators can be categorised into three sets of sub-indicators, where we determine technological, economic and environmental indicators. We can conduct the LCA analyses assisted by benchmarks, during which the starting condition and goal condition of the system are determined. The difference between the two states will become the framework of the road towards making the system achieve a circular economic state. Filling the designed model with data, and evaluating its operations only include the orientation assessment of producing base materials in the current phase of the analysis. However, using this, the systems of Hungary become applicable to a comparison with the Netherlands' systems, albeit only in their basic attributes (Figure 8).

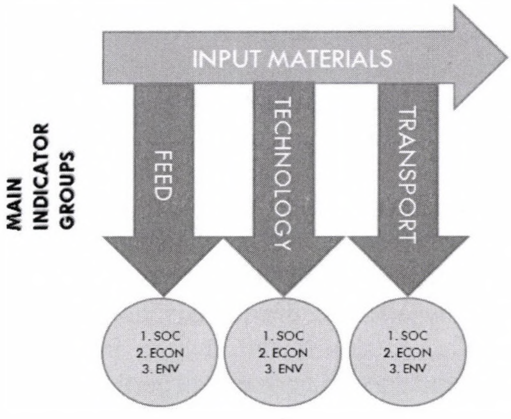

Figure 8. First phase of milk products' life cycle

In the case of base material production, the indicators evaluated can be summarised by analysing the social/economic/environmental aspects of transport needs related to feed production, sustainability of technological solution used, and operation of the system. After cross-referencing the results of the analyses, we defined the Circular Economy Value percentage value, which is defined by the optimal (CEV = 100%) technological solution according to the Dutch circular economy definition (Figure 5). Table 2 summarises the overall data of the analysis, according to technological solutions used. As for the working conditions of domestic extensive (LILO), intensive (HIHO), and optimised (LIHO) systems, we have to note that if we compare them to Dutch categories, the average yield index value of Hungarian systems - 8.000-11.000 kg/cow/lactation - isn't significantly higher than the output value of the Dutch extensive model. Therefore, comparing the Dutch and Hungarian system elements is rather difficult, as the input side's characteristics is entirely different, and we can also come to a multitude of incorrect conclusions when comparing the output dimensions.

Table 2. Systems evaluated, and their related CEV% values

TECHNOLOGY	INDICATORS ANALYSED	CEV VALUE %
LOW INPUT –LOW OUTPUT (LILO) (EXTENSIVE)	Feed production	68.00 %
	Technology usage	76.00 %
	Transport total	74.00 %
	ΣCEV_{LILO}	**72.60 %**
HIGH-INPUT –HIGH OUTPUT (HIHO) (INTENSIVE)	Feed production	58.00 %
	Technology usage	66.00 %
	Transport total	60.00 %
	ΣCEV_{HIHO}	**61.30 %**
LOW-INPUT –HIGH OUTPUT (LIHO) (OPTIMISED)	Feed production	71.00 %
	Technology usage	74.00 %
	Transport total	74.00 %
	ΣCEV_{LIHO}	**73.00 %**
CEV VALUE OF BASE MATERIAL PRODUCTION:		BETWEEN 61.3 % and 73 %

4. Conclusion

Based on the circular models of the Netherlands, we were able to determine that guiding the linear production models into a sustainable circular system can be defined well in production systems, which have clear demand and supply relations, and the frequent intervention processes don't have an impact on the usage of various resources. Based on the Dutch example, we can also see that the fundamentals of circularity can help coordinate competitiveness and sustainability. This is due to how circular economy can help separate economic growth from the limitless consumption of resources, by which the mentioned resources' renewable attribute can achieve a net positive effect. During the evaluation of the Dutch analyses, it became apparent how neither a high concentration of negative externalities, nor that of positive externalities can be found in circular production systems. Too many positive externalities impair the financial sustainability, as we could see in the extensive Dutch model, whereas too many negative externalities (basically import content) may mean a cheaper product on the market, but isn't acceptable from society's perspective. We couldn't satisfactorily categorise domestic milk production systems - mainly due to differences in technology - using the Dutch indicators. Therefore, we made three generic production categories or models (extensive, intensive and optimised) in the production size dimensions, which have at least 200 cattle, and conduct activities in milking houses. This production context covers approximately 90% of Hungary's milk production, uses manure management also applicable to the EU practice, has a milking house and stables of sufficient technological level, and may aim to reach sustainable or circular system changes during its choice of strategy.

By rendering parameters to the indicators used for the various production models, and determining the Circular Economic Values, we were able to assess the Hungarian milk productions' technological solutions' sustainability level. The detailed analysis chart in Annex 1 clearly shows that the intensive (HIHO) production systems have multiple linear production components, which guide the system applications away from the closed cycle development of various processes. The 63.10% CEV value may mean a significant need for correction in the future for economic actors, who choose this system for their dairy farms. However, in the cases of the extensive (LILO) and optimised (LIHO) system models, we can see that they're significantly more closed, and follow the circular solutions with much more discipline (CEV = 73%). Based on theoretical correlations, we could assume that the extensive (LILO) model has better performance during the calculation of CEV values, yet, we saw that we got a higher CEV value at the end of our analysis for the optimised model operating with low input and high output. This relationship also clearly shows that systems which weigh the process with the least amount of (positive and negative) externalities are preferred for either sustainability, or circular system descriptions. Also, these systems are able to avoid these external effects in the long-term. In this relation, the Dutch and Hungarian milk production analysis results were identical.

In the case of Hungarian models, it's advised to set the general goal of reducing the culling rate (by 10-80%) – in order to achieve a transition towards circular economic practice – which may bring fundamental changes in the sector's environmental emissions (energy, water and waste management together). In the case of extensive (LILO) systems, the goal may be to reduce GHG emission for feeding practice, whereby the economic indicators can also be improved. The sustainability or circularity of intensive (HIHO) systems should be intensified, which may be achieved most notably by reducing the input content of feed, by which it's also possible to increase the positive effects the system that has on biodiversity, and import market risks may be avoided. For intensive systems, drastic reduction in culling rate may cause a significant change in both waste management and efficient animal performance. As for the optimised (LIHO) model, a significant improvement may be achieved by increasing the ratio of home-grown protein in the feeding practice, which brings them closer to circular systems. Also, the goal-specific increase of forage ratio which takes GHG emission aspects and lactation periods into consideration is also advised.

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Annex 1: Summarizing chart relating to the calculation of Circular Economic Value (CEV) (evaluated by using data calculated with the Livestock Performance Testing Ltd. database, and expert estimations)

INDICATOR FEED	$FEED_{LILO}$	$FEED_{HIHO}$	$FEED_{LIHO}$
Nutrient circulation	0.70	0.50	0.65
Social acceptance and assistance	0.75	0.50	0.60
Mass feed quotient	0.70	0.50	0.60
Mass feed quality	0.65	0.65	0.95
GHG emission (from digestion)	0.60	0.75	0.75
CEV VALUE %	**68%**	**58%**	**71%**

INDICATOR TECHNOLOGY	$TECH_{LILO}$	$TECH_{HIHO}$	$TECH_{LIHO}$
Import feed costs and its effect on circularity	0.75	0.60	0.70
Improving biodiversity	0.85	0.50	0.75
Lactation production	0.70	0.85	0,80
Milking average	0.65	0.85	0.75
Average number of lactations	0.80	0.50	0.70
CEV VALUE %	**76%**	**66%**	**74%**

INDICATOR TRANSPORT	TRA_{LILO}	TRA_{HIHO}	TRA_{LIHO}
Home grown protein feed usage	0.80	0.50	0.60
Import input feed (cost), and its effect on decreasing transport costs	0.75	0.60	0.75
Area of milk processing (less advantageous value means higher export ratio and transport)	0.60	0.80	0.70
Avoiding dairy product and waste transportation (waste processing costs)	0.85	0.50	0.85
Transporting material flows, input-output ratio (efficiency of material usage)	0.70	0.60	0.80
CEV VALUE %	**74%**	**60%**	**74%**

SUM CEV %	**72,6%**	**61,3 %**	**73 %**

Affects circularity:
Strongly supports circularity:

CEV%: defines how the analysed system or system element performs on average at the time of the analysis, compared to the system realising perfect circulation, meaning the optimal system (determining the maximum values of the circular framework - 100% - was done based on the Dutch example). See Figure 5!

Abbreviations:

$FEED_{LILO,HIHO,LIHO}$ = Indicator values related to feed production for the various technological solution variants

$TECH_{LIHO,HIHO,LIHO}$= Indicator values related to technological solutions used for the various technological solution variants

$TRA_{LIHO,HIHO,LIHO}$= Indicator values related to transport needs used for the various technological solution variants

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ANALYZING WASTE MANAGEMENT WITH RESPECT TO CIRCULAR ECONOMY

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Abstract

The term 'Circular Economy" (CE) currently is very popular with economists and on the political agenda. Policy makers, academics and world business leaders emphasize that moving towards a circular economy has a crucial importance in solving global environmental and economic problems. In this present paper, we intend to highlight the most important notions of (CE) with respect to waste management. Before we analyze the key concepts of circular economy, it is important to review the development and major events of the past in connection with global environmental challenges. The paper presents the possibilities of circular economy by reviewing specialist literature and analyzing data. The data of the Eurostat were used for evaluation. Conclusions are drawn on the basis of facts and analyses that could help understand the necessity and development of circular economy.

Keywords

circular economy, sustainable development, waste management, EU waste targets

1. Introduction

Each year humanity uses resources and ecosystem services that would require 1.5 Planet Earths to be able to keep up with and support our societies [1]. Humanity is facing big challenges: climate crises, financial crises, global poverty, ozone depletion, extinction of species, epidemics, deforestation, armed conflicts, fresh water shortage, social anxiety, natural disasters and so on. We are daily faced by alarming reports about the state of nature and humanity. Research finding, such as the Millennium Ecosystem Assessment [2], Planetary Boundaries [3, 4], Ecological footprint [1] and IPCCs [5], have drawn the same conclusion that the natural cycles, ecosystems and natural resources are being degraded and altered by human impact and the environmental problems are serious.

Human activities have, since the start of industrialism –including fossil fuel dependence and industrialized agriculture – destabilized the Earth systems and natural cycles and forced the environment into a destabilized state [3].

Four major causes of environmental problems are population growth, wasteful and unsustainable resource use, poverty and a failure to include the harmful environmental costs of goods and services in market prices [6].

Due to the forthcoming crisis endangering our planet, the commission of the UN proposed the one-time Norwegian prime minister in 1983 to work out a thorough program to outline the necessary changes. The Brundtland Committee submitted their report in 1987 entitled 'Our Common Future' that caters for the principles and requirements which would save the Earth for future generations should they be met [7].

The most important message of the Report is that forced growth could lead to the breakdown of the biosphere. That is why economic growth should no longer be carried out in its present form. Sustainable development does not call for limiting our demands, rather, it urges us to meet the requirements by minimizing materials and energy as well as the negative consequences of our production. The governments of the developed civil democracies have worked out several environmental programs but none of them have considered the fact that the standard of satisfying needs must also be lowered in some uneconomical societies and it is not enough to rationalize only consumption.

The concept of sustainable development has gained ground in environmental sciences within a short time. However, there is still some confusion in terms of sustainability and sustainable development [8] distinguishes environmental sustainability, economic sustainability, social sustainability and sustainable development. Economic sustainability equals environmental sustainability as both of them refer to the sustainability of stock. The definition above takes Hicks' terms of income into account [9] according to which income is the maximum income that can be spent without reducing real consumption in the future. Social sustainability means the sustainability of social capital. Sustainable development refers to all the three terms in this interpretation.

According to the report Our Common Future [7] it is such a development that ensures meeting the demands of the present without compromising the satisfaction of the needs of future generations. According to another interpretation it means improving the quality of human life within the sustaining capacity of supporting ecosystems [10].

Meadows et al. [11] defines sustainable society as the one that can be sustained for generations and it is careful enough not to ruin its vital system.

According to Daly [12] three criteria must be met to achieve material and energy sustainability. They are as follows:

- the rate of renewable resources must not exceed regeneration rate;
- the rate of non-renewable resources must not exceed the regeneration rate of sustainable renewable ones and
- the emission rate of pollutants must not exceed the assimilative capacity of the environment.

Opschoor [13] introduces the time concept as it states

- the time concept of human interaction must be in balance with the time concept of natural processes if we take either the degradation of waste or the regeneration rate of renewable resources and ecosystems into account.

The most important message of sustainable development is treating the right of satisfying the needs of future generations on a level-playing field with the right of the present generation. On the basis of the prerequisites for sustainability Tietenberg [14] states that the previous generations can make use of the resources until the level of well-being of the future generations reaches at least the level of any previous generation. If the well-being of people is lower than at present as a consequence of taking resources away, it does harm the criterion of sustainability.

Of the several kinds of interpretations of sustainable development [15] distinguishes three basic types.

1. Sustainability can be interpreted as constant consumption. This corresponds with the weak sustainability criterion where natural and man-made stock can substitute each other. Total output of production and the standard of consumption per capita can be maintained as long as the profit gained from using natural resources is not consumed, rather invested in funds.
2. The term can be interpreted as the constant stock of natural resources in time. This corresponds with sustainability in its strict sense, i.e. natural and man-made capital can complement but cannot substitute each other.
3. Sustainability can also be interpreted as equality between generations. There is no further rule concerning the substitution of natural capital with man-made one.

The United Nations Conference on Environment and Development, which took place in 1992 in Rio de Janeiro, has been a cornerstone of modern sustainable development policies and has strongly influenced the direction they have taken. It has enabled a consensus between the otherwise conflicting objectives of economic growth, social equity and environmental protection by embracing the multi-dimensional concept of sustainable development. The Rio Declaration on Environment and Development also known as the Rio Declaration, and Agenda 21 were the major outcome documents of the Rio conference.

Twenty years after the first Rio conference, the United Nations Conference on Sustainable Development (UNCSD) was held in June 2012, again in Rio de Janeiro – therefore also called 'Rio+20' The conference has been conceived as a landmark event in the global movement for sustainable development. As the main outcome, world leaders decided to launch a process for the development of a set of Sustainable Development Goals (SDGs), which will constitute the goals of the 2030 agenda for sustainable development, thus replacing the MDGs after 2015.

Following the Rio+20 Conference, the UN launched a post-2015 process, which culminated in the definition of the 2030 agenda for sustainable development. The 2030 agenda, approved in September 2015 by the UN General Assembly (27) defines sustainable development goals and targets, refers to the development of a global indicator framework and calls for revitalized global partnership to ensure its implementation. Many actors at the political, technical and scientific level are involved in the definition of the different elements of the 2030 agenda. Several international organizations, as well as stakeholders from the civil society and the private sector have been involved at different stages of the post-2015 process.

The Europe 2020 strategy (Table 1.) adopted by the European Council in 2010 is the EU ten-year strategy for growth and jobs. It puts forward three priorities to make Europe a more sustainable and more inclusive place to live:

–It envisages the transition to smart growth through the development of an economy based on knowledge, research and innovation.

–The sustainable growth objective relates to the promotion of more resource efficient, greener and competitive markets.

–The inclusive growth priority encompasses policies aimed at fostering job creation and poverty reduction.

Table 1. The Europe 2020 strategy's key priorities, headline targets and flagship initiatives [16]

	Targets	Flagship initiatives
Smart Growth	— 3 % of GDP to be invested in the research and development (R&D) sector. — Reduce the rates of early school leaving to below 10 %, and at least 40 % of 30 to 34 year olds to have completed tertiary or equivalent education.	— Innovation Union — Youth on the move — A digital agenda for Europe
Sustainable Growth	— Reduce greenhouse gas emissions by 20 % compared to 1990 levels. — Increase the share of renewables in final energy consumption to 20 %. — 20 % increase in energy efficiency.	— Resource efficient Europe — An industrial policy for the globalisation era
Inclusive Growth	— 75 % of 20 to 64 year old men and women to be employed. — Reduce poverty by lifting at least 20 million people out of the risk of poverty and social exclusion.	— An agenda for new skills and jobs — European platform against poverty and social exclusion

The linear economy is a definition for the present economic growth model. In this model "linear" refers to cradle to grave flow of natural resources (take-make-waste). This linear flow is the consequence of cheap and amply resource of supplies leading producers to focus on supplying customers increasing amount of goods. In this model, environmental impact is unaccounted for. The incentives to minimize waste during use and product end-of life are weak. No attention is paid to ensure discarded goods are put into new use or back into a production process as raw material [17]. A linear economy flows like a river, turning natural resources into base materials and products for sale through a series of value-adding steps [18]. At the point of sale, ownership and liability for risks and waste pass to the buyer (who is now owner and user). The owner decides whether old tires will be reused or recycled – as sandals, ropes or bumpers – or dumped. The linear economy is driven by 'bigger-better-faster-safer' syndrome – in other words, fashion, emotion and progress. It is efficient at overcoming scarcity, but profligate at using resources in often-saturated markets. Companies make money by selling high volumes of cheap and sexy goods.

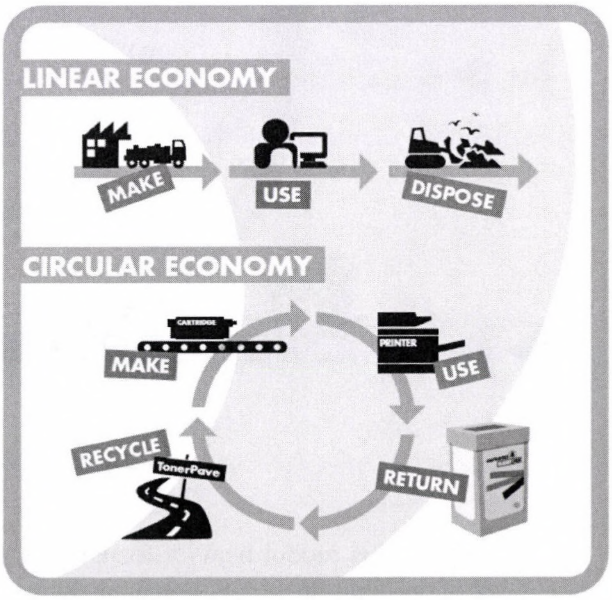

Figure 1. Linear vs circular economy [19]

2. Circular Economy

The starting point for the ideas on CE has been to change the linear economic system of take-make-waste in order to lower resource use and waste of natural capital. It builds on the notion of cycles in nature fueled by solar energy, where nothing is wasted but just goes around in loops. Figure 1 illustrates the difference between a linear and circular economy.

In nature, materials cycle endlessly and nothing is wasted, but humans have developed a linear approach of producing, consuming and disposing of items. The idea of a circular economy, a closed loop process in which we reuse, recover and recycle these valuable materials and keep them in the productive economy for as long as possible, is gaining traction in many business processes (Figure 2). A circular economy is like a lake. The reprocessing of goods and materials generates jobs and saves energy while reducing resource consumption and waste. Cleaning a glass bottle and using it again is faster and cheaper than recycling the glass or making a new bottle from minerals. Vehicle owners can decide whether to have their used tires repaired or whether to buy new or retreaded replacements – if such services exist. Rather than being dumped, used tires are collected by waste managers and sold to the highest bidder.

Circular-economy business models fall in two groups: those that foster reuse and extend service life through repair, remanufacture, upgrades and retrofits; and those that turn old goods into as-new resources by recycling the materials.

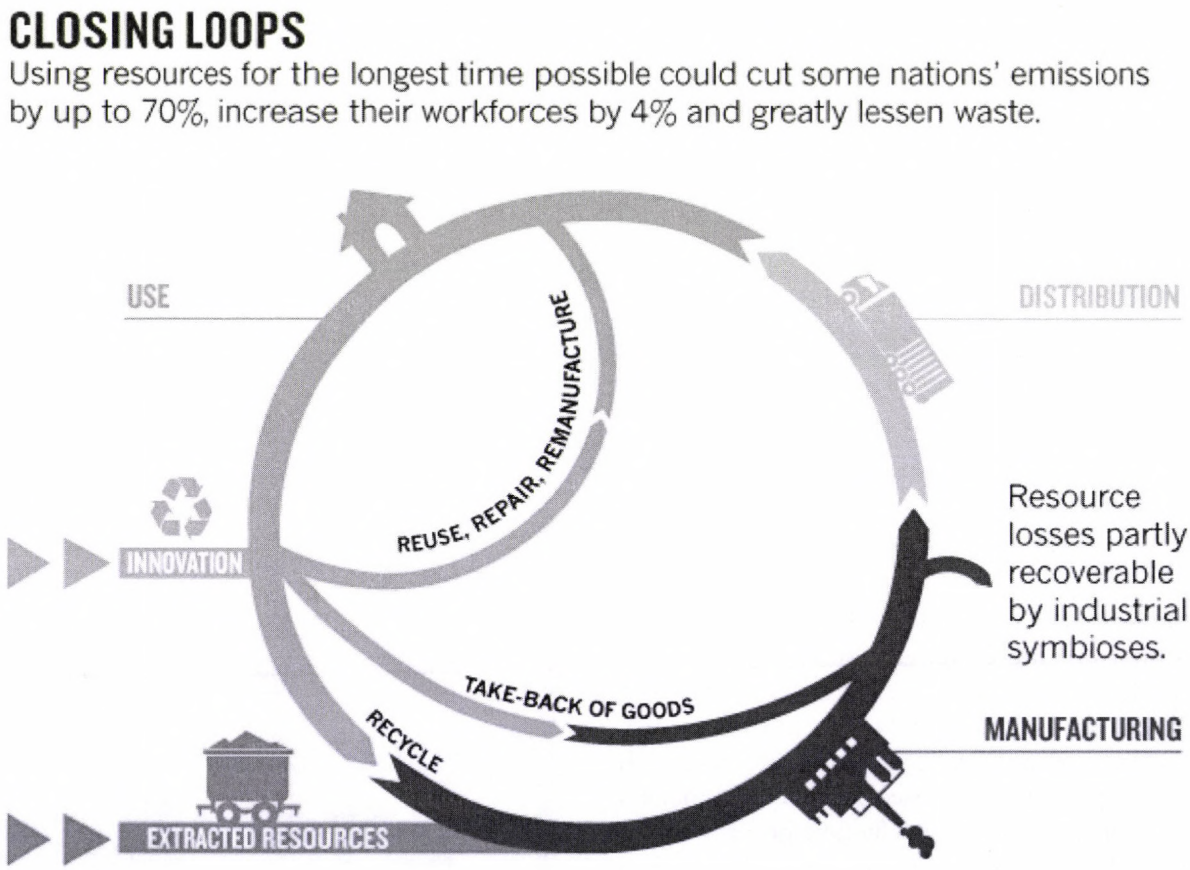

Figure 2: Closing the loop [20]

The concept of this model heavily focuses on the urgent need of decoupling: a transition to an inclusive and circular economy. Decoupling refers to the ability of an economy to grow without corresponding increases in energy and resource use (source limits) and in environmental pressure (sink limits). A decoupled economy should ideally not negatively affect soil fertility and biodiversity, not diminish resource stocks and not lead to increased toxicity of land, water and air. Relative decoupling will buy time, i.e. give the economy some extra time before it runs into resource constraints and/or excess pollution. Once the economy comes close to a boundary, absolute decoupling will be a requirement so as to enable the economy to continue to develop sustainably. While relative decoupling of economic growth from resource use has been happening over the past decades (Figure 3.), the gains made so far have been rapidly eaten up by a combination of economic growth and the so-called rebound effect, i.e. that the resources freed up by increased efficiency are used up very soon through increased consumption. Here is where the circular economy as a powerful concept can be applied [21].

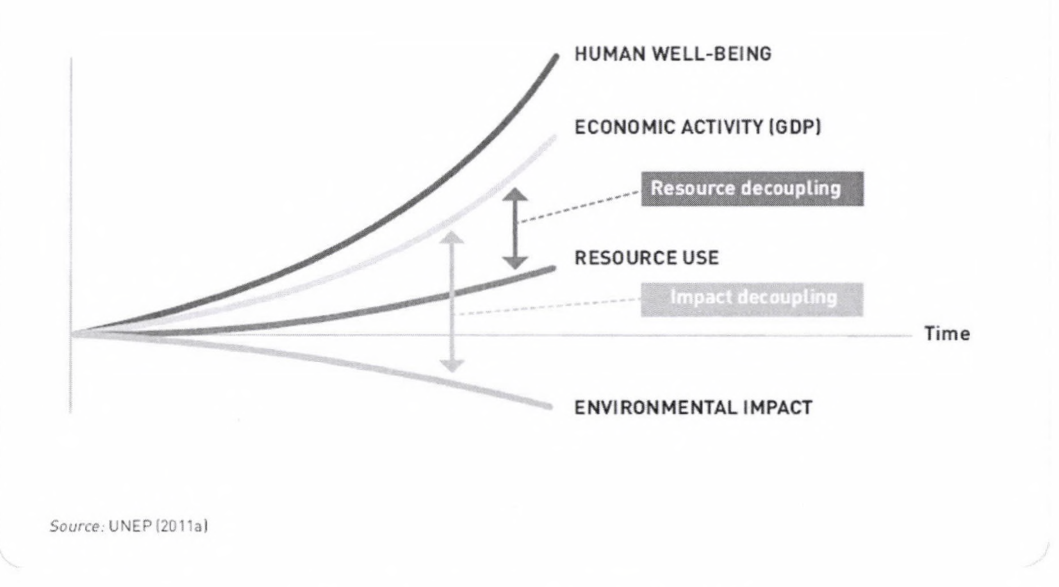

Figure 3. Aspects of decoupling [22]

CE proponents claims CE to be a new paradigm for industry since it aims at generating ecological, social and economic value resulting in effectiveness improving the state of the environment and even go beyond sustainability [23].

The European Commission adopted a so called Circular Economy Package in 2015. The Package includes revised legislative proposals on waste to stimulate Europe's transition towards a more circular economy which will boost global competitiveness. It consists of an action plan establishing a concrete program of action, with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials.

The proposed actions will contribute to "closing the loop" of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy. In the following the most important aspects of the action plan is reviewed.

A circular economy starts at the beginning of a product's life. The design phase and production processes influence sourcing, resource use and waste generation throughout a product's life. Better design can make products more durable or easier to repair. Unfortunately, current market signals appear insufficient to make this happen. The main reason for this can be found in the different interests of producers, users and recyclers. It is essential to provide incentives for improved product design, while preserving the single market and competition, and enabling innovation. Electrical and electronic products are particularly significant in this context. Their reparability can be important to consumers, and they can contain valuable materials that should be made easier to recycle. In order to promote a better design of these products, in the future, issues such as reparability, durability, upgradability, recyclability, or the identification of certain materials or substances will be systematically examined.

The Ecodesign working plan for 2015-2017 will focus on the implementation of reparability, upgradability, durability, and recyclability of products by developing product requirements relevant to the circular economy in the future.

EU consumers often find it difficult to differentiate between products and to trust the information available. Green claims may not always meet legal requirements for reliability, accuracy and clarity [24]. That is why it is inevitable to make green claims more trustworthy, and ensure better enforcement of the rules in place.

Planned obsolescence practices can also limit the useful lifetime of products. Through an independent testing program, extensive work should be carried out to detect such practices. In addition, the revised legislative proposals on waste include new provisions to boost preparation for reuse activities.

Waste management plays a central role in the circular economy: it determines how the EU waste hierarchy is put into practice (Figure 4). The waste hierarchy establishes a priority order from prevention, preparation for reuse, recycling and energy recovery through to disposal, such as landfilling. To achieve high levels of material recovery, it is essential to send long-term signals to public authorities, businesses and investors, and to establish the right enabling conditions at EU level, including consistent enforcement of existing obligations.

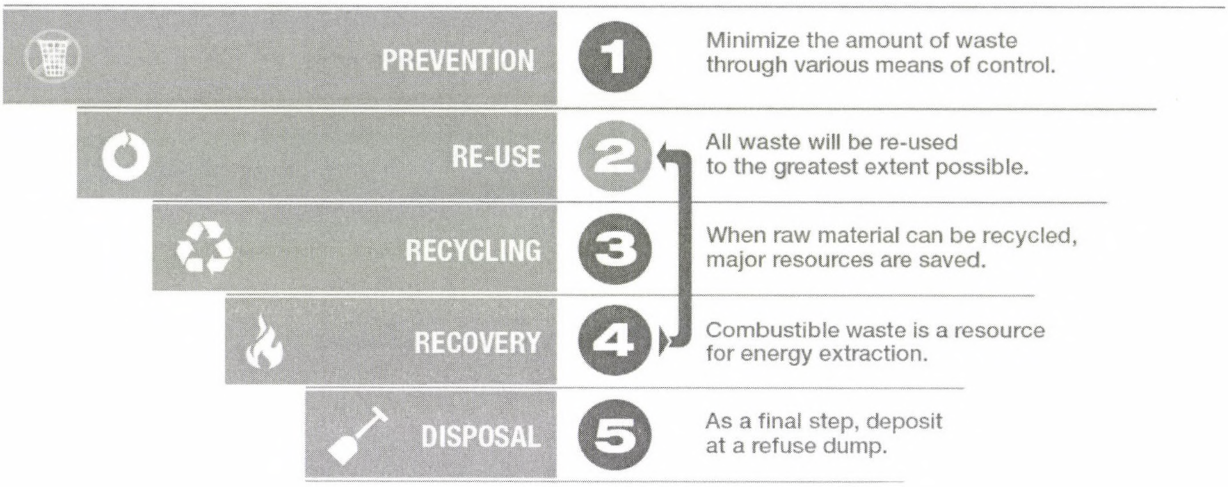

Figure 4. EU's waste hierarchy [25]

Today, only around 40% of the waste produced by EU households is recycled. This average masks wide variation between Member States and regions, with rates as high as 80% in some areas, and lower than 5% in others. New legislative proposals are being put forward on waste to provide a long-term vision for increasing recycling and reducing the landfilling of municipal waste, while taking account of differences between Member States. These proposals also encourage greater use of economic instruments to ensure coherence with the EU waste hierarchy.

The revised waste proposals will also address key issues relating to the calculation of recycling rates. This is essential to ensure comparable, high-quality statistics across the EU, and to simplify the current system and encourage higher rates of effective recycling for separately collected waste.

Another barrier to higher recycling rates is the illegal transport of waste, both within the EU and to non-EU countries, which often results in economically sub-optimal and environmentally unsound treatment.

When waste cannot be prevented or recycled, recovering its energy content is in most cases preferable to landfilling it, in both environmental and economic terms. 'Waste to energy' can therefore play a role and create synergies with EU energy and climate policy, but guided by the principles of the EU waste hierarchy.

The need for integrating natural resources into the development and decision-making processes of various sectors on a political level is becoming apparent in the European Union [26]

The revised legislative proposals on waste set clear targets for reduction of waste. The most important elements of the revised waste proposal are as follows:

- A target for recycling 65% of municipal waste by 2030;
- A target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;
- A ban on landfilling of separately collected waste;
- Promotion of economic instruments to discourage landfilling;
- Simplified and improved definitions and harmonized calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;
- Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

In the following the latest available statistical findings (Figure 5.) are presented in relation with the waste proposal.

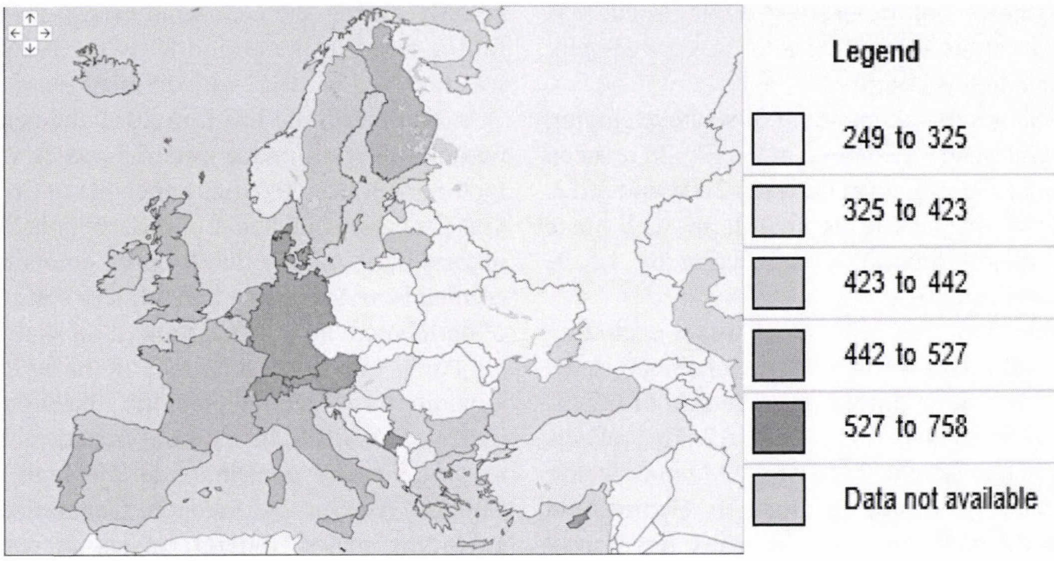

Figure 5. Total waste generated in tons in EU 28, 2014 [27]

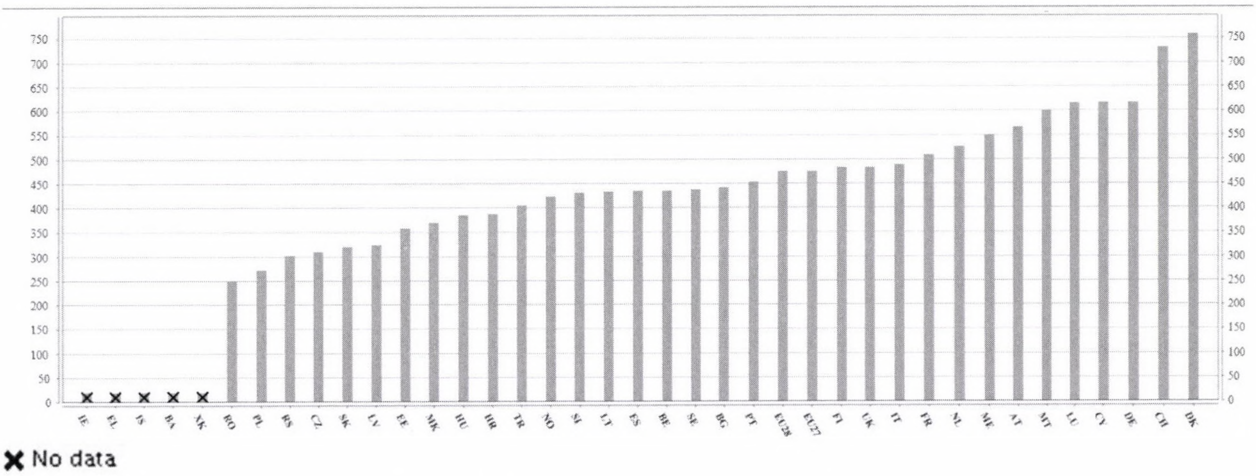

Figure 6. Total waste treatment in tons in EU 28, 2014 [27]

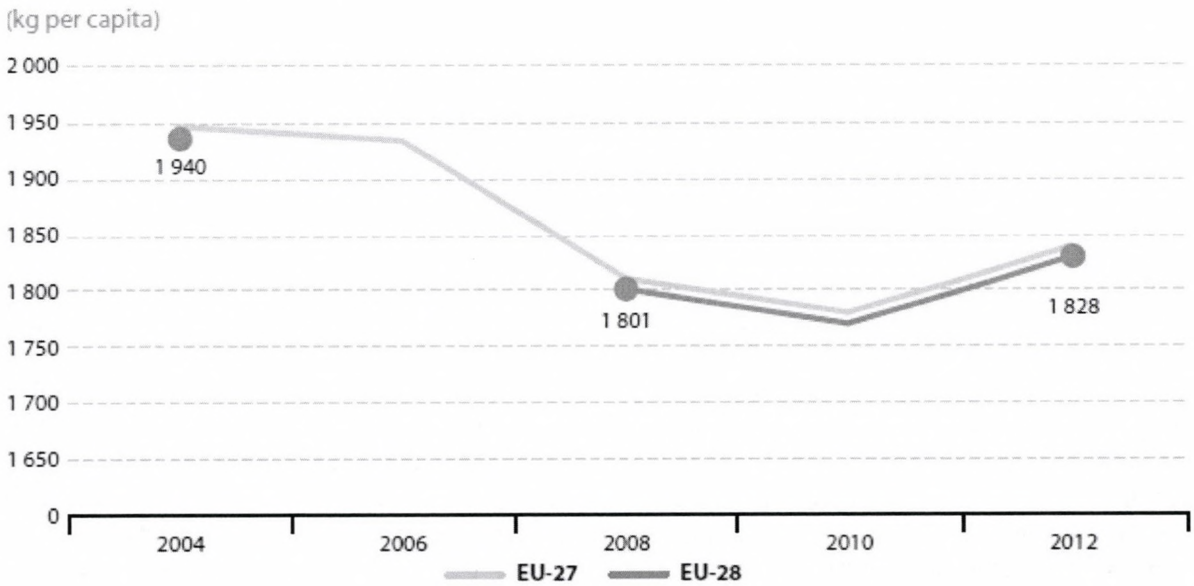

Figure 7. Generation of waste excluding major mineral wastes, 2004–2012 [27]

Figure 6 shows that the greatest waste producer is Germany but at the same time total waste treatment is the highest in this country.

Figure 7 shows that the amount of waste excluding major mineral wastes generated in the EU-28 reduced by 5.8 % over the long term between 2004 and 2012. This trend was reversed in the short term, with waste excluding major mineral wastes rising by 1.5 % between 2008 and 2012.

In the long term, the amount of waste excluding major mineral wastes generated per inhabitant in the EU-28 declined at an annual average rate of 0.7 %, from 1.9 tons in 2004 to 1.8 tons in 2012. This reflects reductions in almost two-thirds of the Member States, with particularly strong declines in Cyprus and Croatia. In the short term, the indicator has started growing at a rate of 0.4 % per year, from 1.8 tons per capita in 2008. The EU experienced a substantial drop in the amount of waste excluding major mineral wastes between 2006 and 2008 (6.5 %). This was most likely affected by the slowdown in economic activity during the economic crises. However, the falling trend in the period between 2006 and 2010 was reversed in 2012, with an increase of 3.3 %.

At Member State level, in 2012 the generation of waste excluding major mineral wastes varied by a factor of 13, from 0.6 tons per capita in Croatia to 8.6 tons per capita in Estonia. The exceptionally high rate in Estonia is mainly due to large amounts of waste coming from the energy and refinery sector as a result of enrichment and incineration of oil shale. This also explains the high amount of hazardous waste generated in Estonia (see the 'hazardous waste' indicator on p. 89). In addition, considerable amounts of wood waste contribute to the high figures in Finland, Austria and Sweden. Generation of waste excluding major mineral wastes decreased in 17 Member States between 2004 and 2012, with the strongest decreases occurring in Cyprus (63 %), Croatia (45 %) and Austria and Hungary (39 % each).

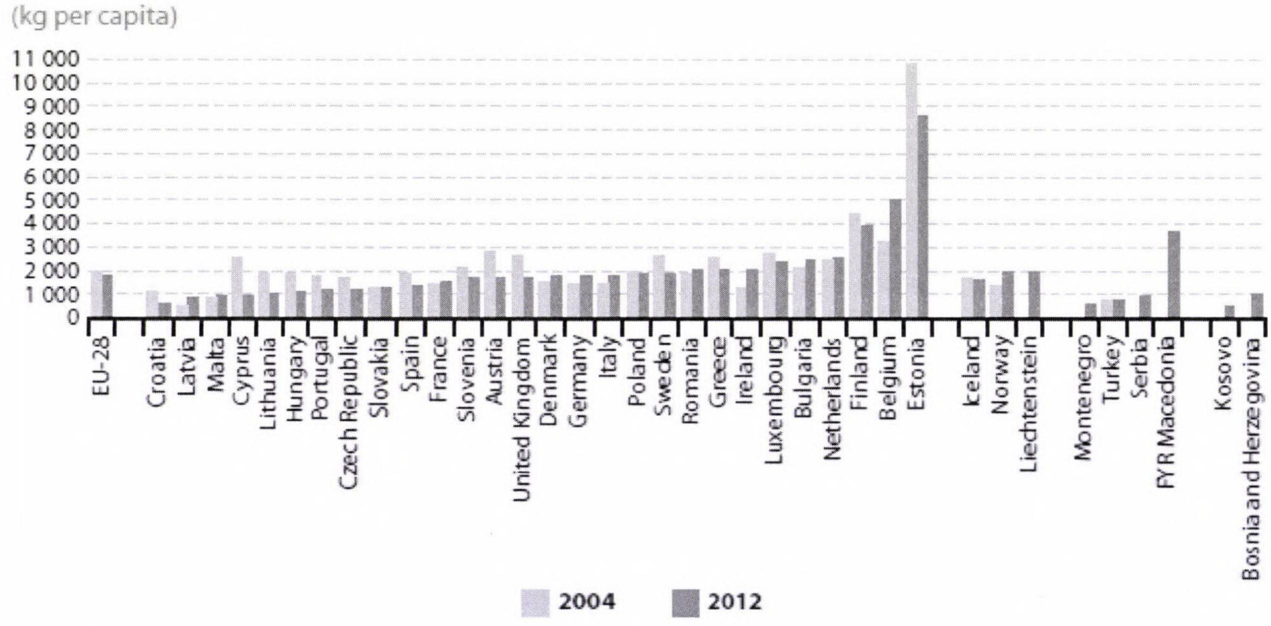

Figure 8. Generation of waste excluding major mineral wastes, by country, 2004 and 2012 [27]

Waste excluding major mineral wastes (Figure 8.) is an important indicator for environmental policies because it covers most of the waste for which reduction is an important environmental objective. Although the indicator focuses on waste excluding major mineral wastes, it is considered to reflect the general trend in waste generation more accurately and in a more comparable way than the total including mineral waste. This is because of the strong fluctuations in waste generation in the mining and construction sectors, and their limited data quality and comparability. Moreover, for a considerable share of mineral wastes, prevention is not the main environmental objective. This indicator presents the amount of waste excluding major mineral wastes generated, expressed in kilograms per capita and per year. The indicator covers hazardous and non-hazardous waste from all economic sectors, administrations and households, including waste from waste treatment (secondary waste) but excluding major mineral waste, contaminated soils and dredging spoil.

The EU recovered and reprocessed 52 % more waste through recycling and composting in the long term, between 2000 and 2013. In the short term, the share of recycling and composting increased from 36.3 % in 2008 to 41.8 % in 2013. The shift away from disposal was driven by EU and national strategies for sustainable waste management.

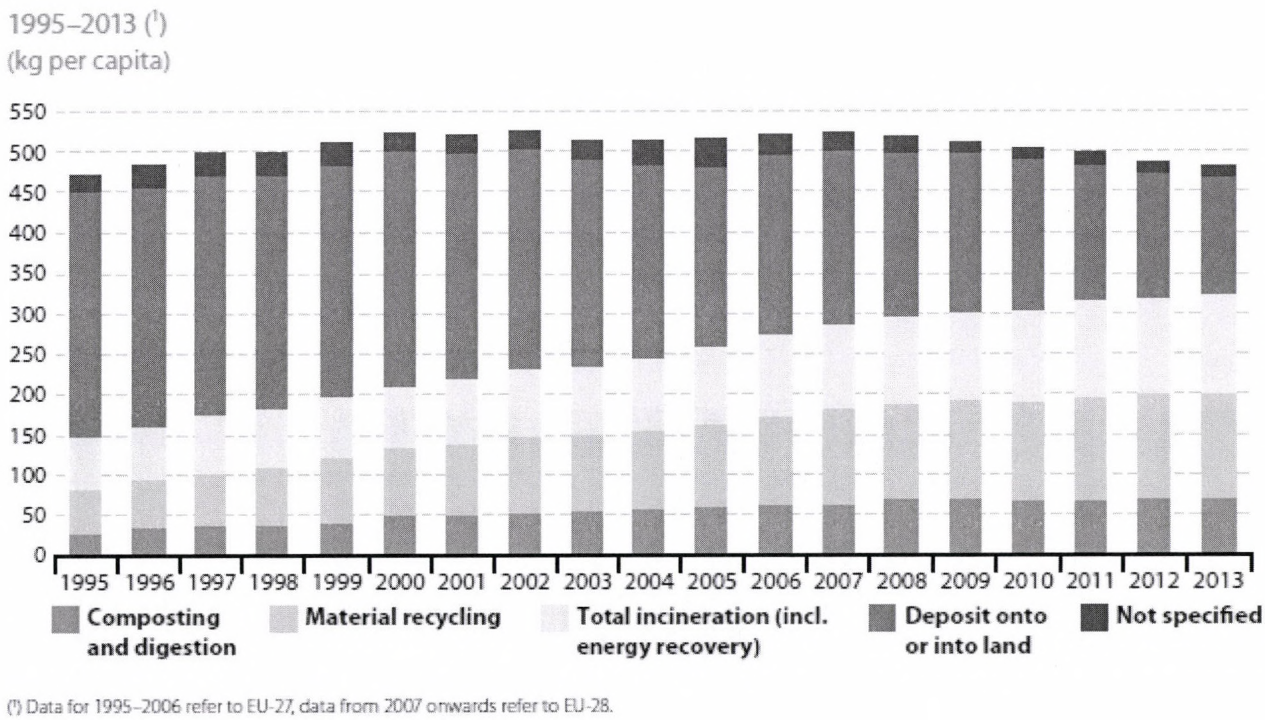

Figure 9. Municipal waste generation and treatment, by type of treatment method, EU-28, 1995–2013 [27]

In the long term, the average amount of municipal waste (Figure 9.) generated per EU inhabitant fell from 1.43 kg per day in 2000 to 1.32 kg per day in 2013. Between 1995 and 2000 the amount of total municipal waste generated annually in the EU was gradually increasing, from 455 to 499 kg per inhabitant. In the following period, between 2000 and 2007, total EU municipal waste was more or less stable, fluctuating within the range of 514 and 523 kg per inhabitant. It was only in the short term, between 2008 and 2013, coinciding with the onset and aftermath of the economic and financial crises, that the total amount of generated municipal waste started to fall steadily, reaching 481 kg per person in 2013.

In 1995, 64 % of municipal waste generated in the EU-28 – originating from everyday household waste and other sources such as commerce, offices and public institutions — was disposed at landfill sites. In 2000, more than half of municipal waste was still being landfilled (55.1 %). But by 2013 there had been a clear shift towards recycling and composting (41.8 %) and incineration with energy recovery (25.4 %). Waste prevention – the top aim of European policy's 'waste hierarchy' — also seems to have been taken up across Member States, with 18 out of 31 countries having adopted waste prevention programs by the end of 2013 as required by the EU Waste Framework Directive. The observed improvements in waste management have been to a large extent driven by EU and national strategies prioritizing efficient waste management through various instruments. These include setting targets for recycling and recovery, imposition of taxes and other restrictions on landfill waste. The trend towards sustainable municipal waste management has also been reinforced by some external factors such as the increase in urbanization and population densities and the rise in prices of raw material, recycled materials and fuels.

The amount of total municipal waste treatment in the EU varied from 747 kg per inhabitant in Denmark to 220 kg per inhabitant in Romania in 2013. Despite the large body of EU waste legislation, which has been in place for about 20 years, the dynamics of waste treatment vary greatly among Member States. Whereas Romania landfills more than 96.8 % of its municipal waste and Malta, Croatia, Latvia and

Greece more than 80 %, Germany, Sweden and Belgium dispose of less than 1 % in this way. In large part, the vast differences in countries' performance can be explained by their different starting positions, the existence of derogation periods for some, and the fact that some had started increasing municipal waste recycling long before they were required to by EU policies. However, formal transposition of EU law into national legislation is often not sufficient for achieving EU's minimum target levels on waste management. In general, better performing countries in terms of landfilling and recycling tend to have a wider range of instruments and measures in place. These include active recycling policies in combination with 'landfill bans on biodegradable waste or non-pre-treated municipal waste; mandatory separate collection of municipal waste types, especially bio wastes; and economic instruments such as landfill and incineration taxes and waste collection fees that strongly encourage recycling'. Member States with dedicated and diverse policy instruments and strict regulations on waste management, such as Sweden and the Netherlands, deliver relatively high recycling (including composting) and incineration rates, both above 45 %. The large discrepancies across Member States reflect some gaps in the implementation of EU waste objectives into national legislation. These gaps are due to a series of technical, market or administrative barriers.

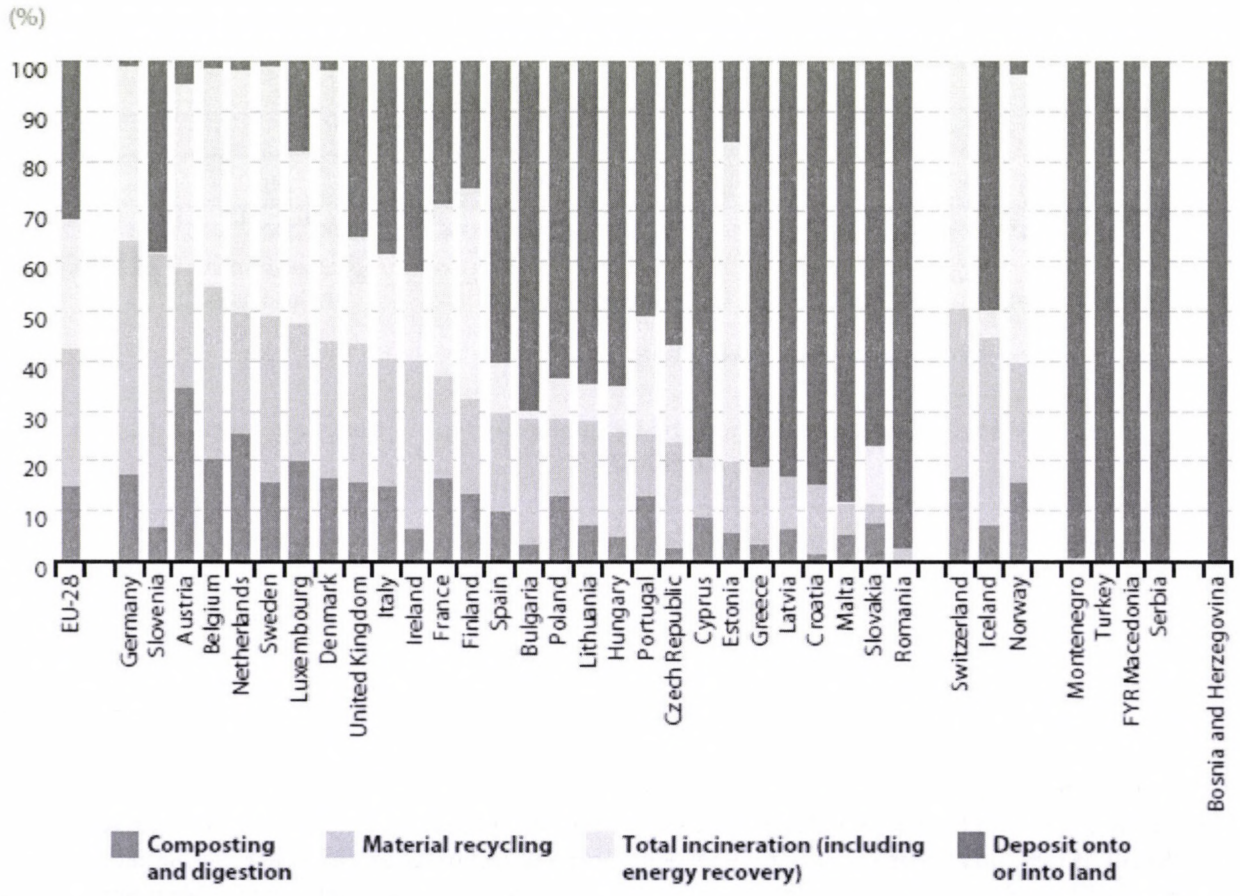

Figure 10. Municipal waste treatment, by type of treatment method, by country, 2013 [27]

At the international level, Europe is outperforming countries such as the United States and Japan with regard to shifting waste management practices away from landfilling and incineration towards more environmentally friendly ones such as recycling. More than 40 % of Europe's waste is recycled or composted (Figure 10.). The only country to surpass Europe is the Republic of Korea with almost 60 % of its municipal waste being treated through recycling or composting (Figure 11.).

Waste has become increasingly recognized as an important material resource and potential energy source. In this respect, it can generate economic value and help to decouple resource use from economic growth. Environmentally friendly ways of waste management such as recycling and composting reduce negative environmental impacts on the environment and human health. Increasing the proportion of waste recycled and composted reduces the amount to be disposed of. It also reduces primary resource extraction. The municipal waste treatment indicator presents the amount of municipal waste recovered through recycling and composting as well as the amount disposed of through landfilling and through incineration.

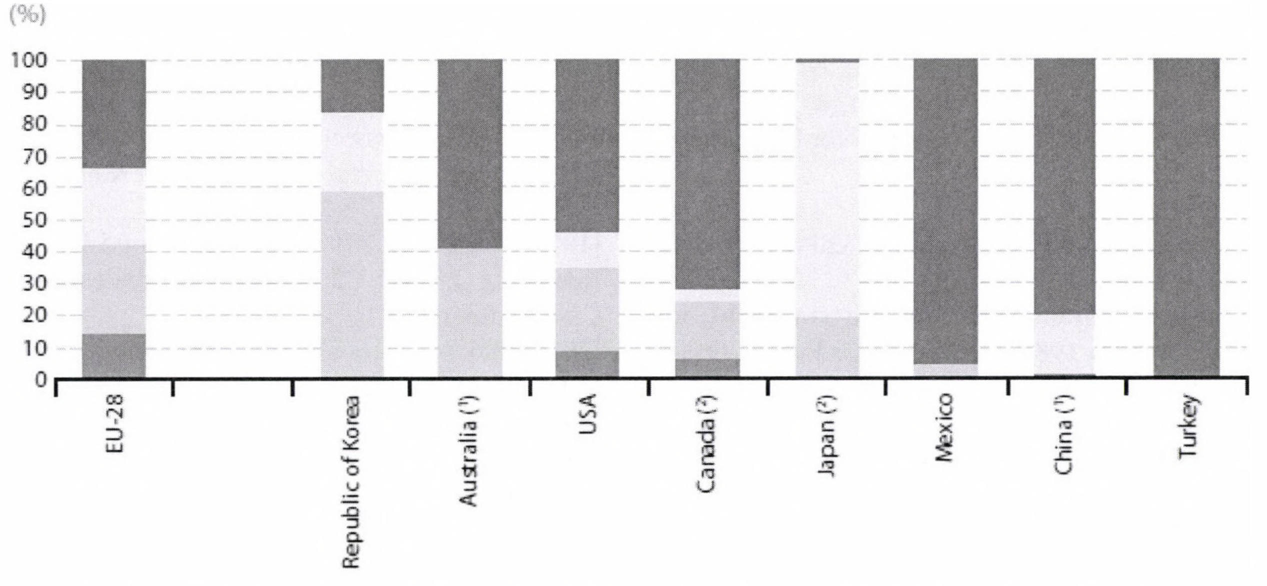

Figure 11. Municipal waste treatment, by type of treatment method, by country, 2012 [27]

3. Conclusion

From the statistical data it can be seen that waste management in the EU improved significantly between 1995 and 2013. Not only did the amount of waste disposed of at landfill sites fall, but the amount of waste recovered and reprocessed through recycling and composting or transformed into energy through incineration also rose. Other actions can be taken to reduce the amount of household waste. This is often more effective at national and local level, where it can be better targeted: awareness campaigns and economic incentives have proven particularly effective. For example, international and local zero waste movements can play a decisive role.

In circular economy landfilling is not supported. this means that funding for new landfill will be granted only in exceptional cases (e.g. mainly for non-recoverable hazardous waste) and that funding for new facilities for the treatment of residual waste, such as incineration or mechanical biological treatment, will be granted only in limited and well justified cases, where there is no risk of overcapacity and the objectives of the waste hierarchy are fully respected

The circular economy could boost the EU's competitiveness by protecting businesses against scarcity of resources and volatile prices, helping to create new business opportunities and innovative, more efficient ways of producing and consuming. It could create local jobs at all skills levels and opportunities for social integration and cohesion. At the same time, it will save energy and help avoid the irreversible damages caused by using up resources at a rate that exceeds the Earth's capacity to renew them in terms of climate and biodiversity, air, soil and water pollution. Wider benefits of the circular economy can be in lowering current carbon dioxide emissions levels. Action on the circular economy therefore ties in closely with key EU priorities, including jobs and growth, the investment agenda, climate and energy, the social agenda and industrial innovation, and with global efforts on sustainable development.

Economic actors, such as business and consumers, are key in driving this process. Local, regional and national authorities are enabling the transition, but the EU also has a fundamental role to play in supporting it. The aim is to ensure that the right regulatory framework is in place for the development of the circular economy in the single market, and to give clear signals to economic operators and society at large on the way forward with long term waste targets as well as a concrete, broad and ambitious set of actions, to be carried out before 2020.

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CONTENTS OF NO 30/2016