PIONEER AND INNOVATIVE STUDIES IN AGRICULTURE, FOREST AND WATER ISSUES

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Editor

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CONTENT

Color Removal with Ultrasonic System from Water Solutions

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ABSTRACT

Textile industry wastewater has serious environmental problems because the dyes that are released into water bodies with the effluent of this industry have mostly persistent, nonbiodegradable, photosynthesis-limiting and toxic characteristics for the aquatic ecosystem. Ultrasound and its hybrid applications with other methods, such as electrochemical treatment, photocatalytic process and bio-sorption, have gained attention as means of eliminating the adverse effects of dyes in water. In this study, the color removal with ultrasound and Fenton treatments was examined, and the efficiency of the hybrid Sono-Fenton application was determined in the simultaneous presence of media ions in water. This study was conducted with Basic Red 29 Dye in the batch-type ultrasonic reactor at 28, 45, 100 kHz ultrasonic frequencies and supplied 100 W power. The highest color removal efficiency of the Sono-Fenton treatment was 91%. Bicarbonate and nitrate ions were more effective than sulfate in the ultrasonic color removal, and the removal efficiency of the hybrid Sono-Fenton treatment increased with nitrate and bicarbonate ions. As a result of the study, Basic Red 29 dye was successfully removed using the hybrid US-F treatment with 20 mg/L Fe^{+2}, 20 mg/L H_2O_2, 500 mg/L HCO_3^-, 50 mg/L NO_3^{-2}, 28 kHz frequency and 100 W power.

Keywords – Color Removal, Basic Red 29, Ultrasound, Fenton, Sono-Fenton, Media Ions.

INTRODUCTION

The wastewater production of the textile industry is notably special and varies with the type of material, production method and goods because the textile industry wastewater has recently gained significant importance in environmental engineering in terms of wastewater volume and characteristic (Husain, 2006; Tegli et al., 2004). The major environmental problem is synthetic dyes that are resistant (Xu, 2001) to biological degradation (Husain, 2006), which remains a challenge to efficiently and accurately treat textile wastewater because of its relatively high level of acidity (Ozen et al., 2005) color and pollution load. Conventional wastewater decolorization methods such as adsorption (Khan et al., 2004), membrane processes (Sakoda et al., 1996) and ion exchange (Zhao et al., 2008) have been used to remove various dyes of these industry effluents to inhibit their negative effects on the aquatic ecosystem. However, advanced wastewater treatment technologies have been developed to more effectively remove the colors and reduce the toxicity (Neamtu et al., 2004; Hsing et al., 2006) of dyes. The electrochemical treatment (Surme and Demirci, 2014), advanced oxidation process (Neamtu et al., 2004; Zhang et al., 2007, 2013; Yaman and Gunduz, 2015), bio-sorption (Tegli et al., 2014; Yesilada et al., 1995; Xie et al., 2011; Kanaraj et al., 2012), nano-sized sorbent application (Zhao et al., 2008; Rasoulifard et al., 2011; Lin et al., 2015) and ultrasound (Ozen et al., 2005; Ai et al., 2010; Zhang et al., 2013; Sancar and Balci, 2013; Wu et al., 2012) can be listed among these alternative technologies.

Basic Red 29 is the most common textile dye, which has the chemical formula of $C_{19}H_{17}ClN_4S$ chemical formula and molecular weight of 368.88 g/mol. The Basic Red 29 is shown in Figure 1 with its molecular formula.

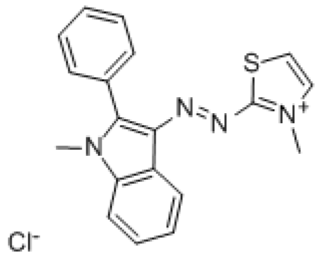

Figure 1. The molecular formula of Basic Red 29

When humans are directly exposed to this dye, it has an irritating effect to the eyes, skin and respiratory system. In previous studies, the decolorization of various textile dyes was investigated with their different natures. Neamtu et al. (2004) obtained 85% and 90% removal efficiencies of color and COD, respectively, after a 10 min Photo-Fenton treatment of Dispersed Red 354 azo dye. Ai et al. (2010) developed the ultrasound and electro catalytic oxidation process to remove Rhodamine B azo dye in aqueous solutions in addition to methyl orange, methylene blue and Reactive Brilliant red X3-B. Zhang et al. (2005) demonstrated that ultrasound with zero valent iron enhanced the reduction efficiency of C.I. Acid Orange 7.

The combinations of ultrasound and their hybrid applications (Ai et al., 2010; Zhang et al., 2007, 2013; Xie et al., 2011; Sancar and Balci, 2013; Wu et al., 2012) with other methods have been noticed to attain more efficient decolorization. Sayan et al. (2008) studied the removal of Reactive Blue 19 dye using ultrasound (US) with the Fenton (F) process. They reported that US with F more efficiently removed color because of the accelerating synergetic effect of two systems. Xu et al. (2001) studied the Reactive Brilliant red X3-B textile dye, which is persistent to UV radiation treatment, with different advanced oxidation processes and obtained the highest decolorization efficiency in the Fe^{+2} –H_2O_2-UV treatment. Voncina et al. (2003) investigated six different reactive dyes with the US-H_2O_2 treatment. They stated that the advanced oxidation process related to the US application with H_2O_2, UV, and ozone accelerated the free-radical formation efficiency because sonication improved the mass transfer and chemical reaction speed. Weng et al. (2014) studied actual textile wastewater and achieved the successful decolorization efficiency using the advanced Fenton process with ultrasound using 1 g/L zero valent iron dosage, 0.01 M hydrogen peroxide concentration, and 47 kHz ultrasonic frequency, but the estimated operating cost was approximately 4.5 USD for 1 m^3 wastewater. Zhang et al. (2007) reported that the combined application of ultrasound and Fenton process did not enhance the color removal of CI Reactive Black 8 combined application compared to the single Fenton treatment, but it improved the COD removal. Zhang et al. (2013) stated that ultrasound and Fenton process supported activated carbon system had 88% decolorization efficiency of Crystal Violet, and the acute toxicity of the dye solution decreased after the treatment based on the Daphnia magna test.

The main parameters that affect the efficiency of ultrasonic decolorization are the ultrasonic frequency, applied power, dye concentration, hydraulic retention time, pH and media ions in water. The media ions in water affect the physical and chemical properties of the liquid, and the change of the type of media ions modifies the pH, direction of mass transfer and chemical reactions during sonication. Thus, the effect of media ions on the color removal with ultrasound must be investigated.

In this study, the color removal of Basic Red 29 Dye with ultrasound (US) and Fenton (F) treatments was studied, and the efficiency of the hybrid Sono-Fenton (US-F) application was determined in the simultaneous presence of media ions in water. This study was conducted at three different ultrasonic frequencies, and the effect of the iron dosage in both Fenton (F) and Sono-Fenton (US+F) treatments was examined.

MATERIALS AND METHODS

The decolorization treatment applications of ultrasound (US), Fenton (F) and their hybrid Sono-Fenton (US-F) process in the simultaneous presence of media ions in water and any media ion are shown this section.

Ultrasonic decolorization

The ultrasonic decolorization studies were performed in a batch-type reactor at three different frequencies: 28 kHz, 45 kHz, and 100 kHz with 100 W power. Basic Red 29 dye was purchased from Sigma Aldrich, and the color removal studies were conducted at 40 mg/L concentration and 100 mL volume of dye. The hydraulic retention time was determined as 30 minutes during the decolorization treatment with ultrasound, and samples were collected from the reactor every 10 minutes during the process. The absorbance of the collected samples was measured using a UV-Vis spectrophotometer (Shimatzu UV-40) at the maximum adsorption wavelength of 506 nm, and the decolorization efficiency was calculated after the treatment. Each experiment was conducted three times at identical conditions, and the average results of all experiments are shown in this paper.

Decolorization with Fenton and Sono-Fenton

Fenton reaction is known as an oxidizing agent of organic compounds under acidic condition by the addition of Fe^{2+} ions and hydrogen peroxide (H_2O_2) (Neamtu et al., 2004; Zhang et al., 2007). Before we performed the hybrid Sono-Fenton process, the model working solution was treated with single Fenton application to explain how the synergetic effect of the hybrid treatment enhances the color removal efficiency. In the decolorization experiments with Fenton process, identical concentration ratios of hydrogen peroxide and Fe^{2+} ion of 0.5-100 mg/L were used. Decolorization with Fenton process was conducted in the batch-type reactor with 30 min hydraulic retention time.

In the hybrid treatment, Fenton process and ultrasound (Sono-Fenton) were performed to enhance the decomposition efficiency of Basic Red 29 as recalcitrant pollutants because the treatment was expected to be considerably more effective than Fenton and ultrasound alone because of their synergic effect. To determine the synergic decolorization effect, Fenton process was performed in an ultrasonic reactor with 28 kHz sonic frequency and 100 W powers in the presence of three different media ions.

Media ion effect on decolorization

Another parameter to consider in the ultrasonic color removal is the presence of media ions such as sulfate, carbonate, bicarbonate and nitrate, which are the dominated ions in the liquid when ultrasound is used in water and wastewater remediation. A large amount of cavitation can be created because the ions form weak points of cavitation initiator in the system. To investigate the effect of media ions in water, SO_4^{-2}, HCO^{-3}, and NO_3^{-2} ions (instead of carbonate ion because of its radical scavenger effect) were added to the system in the form of their water-soluble sodium salts. Na_2SO_4, $NaHCO_3$ and $NaNO_3$ were purchased from Merck Millipore to supply these ions to water. Then, 250-1000 mg/L SO_4^{-2}, 100-500 mg/L HCO_3^{-}, and 50-500 mg/L NO_3^{-2} were added to the working solution to examine their effect on both ultrasound (US) and Sono-Fenton (US+F) processes considering allowable concentrations of these ions in the surface water classification standards.

RESULTS AND DISCUSSION

The results of the decolorization studies at 28 kHz, 45 kHz, and 100 kHz with the 100W power in batch reactors are shown in Figure 2 with no addition to the ultrasonic system.

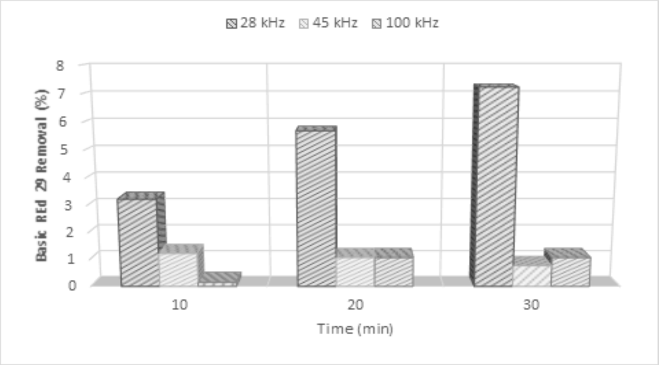

Figure 2. The results of the decolorization studies (28, 45, 100 kHz)

The decolorization efficiency of Basic Red 29 dye using the ultrasonic process in the batch reactor was below 10%, but the highest color removal was determined with 28 kHz frequency during 30 min of the treatment. This poor decolorization efficiency was explained by Ai et al (2010). The chemical effects of US, which caused the thermal decomposition of water molecules into OH^- and H^+ radicals, were likely insufficient for the decolorization of dye in the low-frequency ultrasound application. However, the physical effect of low-frequency ultrasound enhances the efficiencies of other color removal methods such as Fenton, electrochemical oxidation and photocatalytic processes.

Fenton and hybrid Sono-Fenton treatments were performed for the model working solution to enhance the color removal efficiency of ultrasound. The effect of the Fenton and Sono-Fenton processes on decolorization of Basic Red 29 is shown in Figure 3.

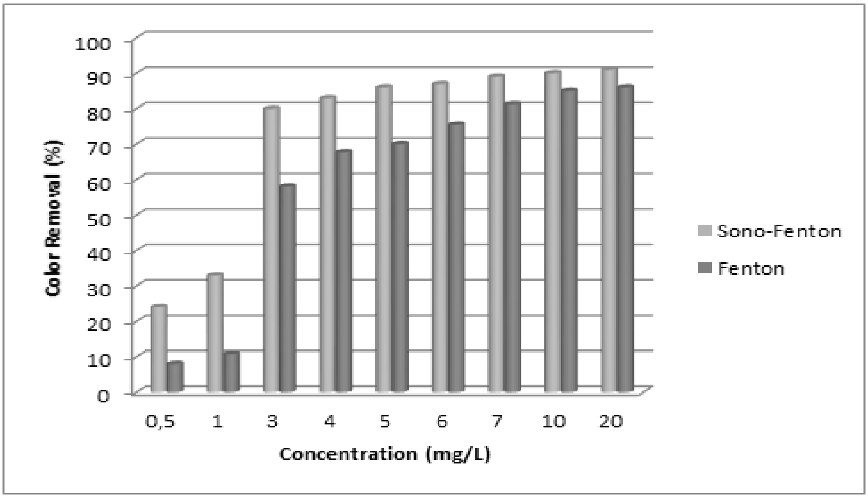

Figure 3. The effect of the Fenton and Sono-Fenton processes on decolorization of Basic Red 29

The optimum decolorization efficiencies of Fenton and Sono-Fenton methods were determined with 20 mg/L Fe^{+2} and 20 mg/L H_2O_2 concentrations. When more than 20 mg/L Fe^{+2} and 20 mg/L H_2O_2 concentrations were supplied to the system, the color removal efficiency decreased because increasing H_2O_2 concentrations might produce the recombination free radicals (Zhang et al., 2013; Wu et al., 2012). Compared to subsequent results with ultrasound and Fenton treatments, the Sono-Fenton treatment enhanced the decolorization efficiency by more than 80%, even if the Fe^{+2} concentration was below 20 mg/L. The physical effects of low-frequency ultrasound improved the decolorization rate by enhancing the Fenton process because of the generation of additional free radicals when there was hydrogen peroxide in water (Xu, 2001; Zhang et al., 2007; Wu et al., 2012). The synergistic effects of ultrasound and Fenton systems was found in the Basic Red 29 removal, as previously reported for dye decolorization by various researchers (Zhang et al., 2007; Zhang et al., 2013; Voncinan and Majcen-Le-Marechal, 2003).

The effect of media ions such as sulfate, bicarbonate, and nitrate in the water is demonstrated in Table 1 for ultrasound and Sono-Fenton treatments.

Table 1: Effect of media ions (sulfate, bicarbonate, and nitrate) in the water for ultrasound (US) and Sono-Fenton (US+F) treatments

Ion Concentration (mg/L)			**Basic Red 29 Removal (%)**
SO_4^{-2}	**HCO_3^-**	**NO_3^{-2}**	
250	-	-	4,36
1000	-	-	8,10
-	100	-	14,50
-	500	-	18,60
-	-	50	15,52
-	-	500	8,80
1000	500	50	84,44 (US+F)
-	500	50	93,07 (US+F)

CONCLUSIONS

The result of the media ion study shows that HCO_3^- and NO_3^{-2} ions increased the Basic Red removal, whereas SO_4^{-2} decreased it. The lowest sulfate concentration and the bicarbonate and nitrate concentrations that positively affected the treatment were studied to explain the simultaneous effect of media ions on the color removal efficiency. In addition, the effects of the media ions were individually and collectively examined because the type of media ions in the water affects the water pH (Tegli et al., 2014; Yaman and Gunduz, 2015; Wu and Wang, 2001). The increase in bicarbonate concentration increased the decolorization efficiency, but the increase in nitrate and sulfate concentrations decreased the color removal efficiency. With the optimal concentrations of three media ions (1000 mg/L sulfate, 500 mg/L bicarbonate and 50 mg/L nitrate) in water, the decolorization efficiency of Basic Red 29 was 84.44% using the Sono-Fenton process. In the experiment with 500 mg/L bicarbonate and 50 mg/L nitrate, the decolorization efficiency of Sono-Fenton increased to 93.07% because sulfate probably reduced the physical effect of low-frequency ultrasound by adsorbing the sonic energy into its molecules at its highest concentration (1000 mg/L) in this study.

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REFERENCE

Husain, Q., (2006), Potential applications of the oxidoreductive enzymes in the decolorization and detoxification of textile and other synthetic dyes from polluted water, *A review Critical Reviews in Biotechnology*, **26(4)**, 201-221.

Khan, T.A., V.V. Singh, and D. Kumar, (2004), Removal of some basic dyes from artificial textile wastewater by adsorption on Akash Kinari coal, *Journal of scientific and Industrial Research*, **63(4)**, 355-364.

Weng, C.H., et al., (2014), Enhancement of the advanced Fenton process by ultrasound for decolorization of real textile wastewater, *Coloration Technology*, **130(2)**, 133-139.

Xu, Y., (2001), Comparative studies of the $Fe^{3+/2+}$-UV, H_2O_2-UV, TiO_2-UV/vis systems for the decolorization of a textile dye X-3B in water, *Chemosphere*, **43(8)**, 1103-1107.

Tegli, S., et al., (2014), Water recycle as a must: decolorization of textile wastewaters by plant-associated fungi, *Journal of Basic Microbiology*, **54(2)**, 120-132.

Ozen, A.S., et al., (2005), Experimental and modeling approach to decolorization of azo dyes by ultrasound: Degradation of the hydrazone tautomer, *Journal of Physical Chemistry A*, **109(15)**, 3506-3516.

Sakoda, A., T. Nomura, and M. Suzuki, (1996), Activated carbon membrane for water treatments: Application to decolorization of coke furnace wastewater, *Adsorption-Journal of the International Adsorption Society*, **3(1)**, 93-98.

Zhao, Z.S., et al., (2008), Rapid decolorization of water soluble azo-dyes by nanosized zero-valent iron immobilized on the exchange resin, *Science in China Series B-Chemistry*, **51(2)**, 186-192.

Neamtu, M., et al., (2004), Decolorization of disperse red 354 azo dye in water by several oxidation processes - a comparative study, *Dyes and Pigments*, **60(1)**, 61-68.

Hsing, H.J., et al., (2006), Evaluation of decolorization, mineralization, and toxicity reduction of tropaeolin O in water by ozonation with UV irradiation, *Ozone-Science & Engineering*, **28(1)**, 9-16.

Surme, Y. and Demirci O.B., (2014), Determination of direct violet 51 dye in water based on its decolorisation by electrochemical treatment, *Chemical Papers*, **68(11)**, 1491-1497.

Lopez-Grimau, V., et al., (2012), Reuse of the water and salt of reactive dyeing effluent after electrochemical decolorisation, *Coloration Technology*, **128(1)**, 36-43.

Jin, Y.P., et al., (2014), Optimizing decolorization of Methylene Blue and Methyl Orange dye by pulsed discharged plasma in water using response surface methodology, Journal of the *Taiwan Institute of Chemical Engineers*, **45(2)**, 589-595.

Bechtold, T., E. Burtscher, and A. Turcanu, (2001) Cathodic decolorization of textile waste water containing reactive dyes using a multi-cathode electrolyser, *Journal of Chemical Technology and Biotechnology*, **76(3)**, 303-311.

Ai, Z.H., et al., (2010), Rapid decolorization of azo dyes in aqueous solution by an ultrasound-assisted electrocatalytic oxidation process, *Ultrasonics Sonochemistry*, **17(2)**, 370-375.

Zhang, H., Y. Zhang, and D.B. Zhang, (2007) Decolorisation and mineralisation of CI Reactive Black 8 by the Fenton and ultrasound/Fenton methods, *Coloration Technology*, **123(2)**, 101-105.

Zhang, H., et al., (2013), Decolorization of Crystal Violet by ultrasound/heterogeneous Fenton process, *Water Science and Technology*, **68(11)**, 2515-2520.

Yaman, C. and G. Gunduz, (2015), A parametric study on the decolorization and mineralization of CI Reactive Red 141 in water by heterogeneous Fenton-like oxidation over FeZSM-5 zeolite, *Journal of Environmental Health Science and Engineering*, 13.

Yesilada, O., K. Fiskin, and E. Yesilada, (1995), The Use of White-Rot Fungus Funalia-Trogii (Malatya) for the Decolorization and Phenol Removal from Olive Mill Waste-Water, *Environmental Technology*, **16(1)**, 95-100.

Xie, J.H., et al., (2011), Decolorization of polysaccharides solution from Cyclocarya paliurus (Batal.) Iljinskaja using ultrasound/H_2O_2 process, *Carbohydrate Polymers*, **84(1)**, 255-261.

Kanagaraj, J., T.S. Velan, and A.B. Mandal, (2012), Biological method for decolorization of an azo dye: clean technology to reduce pollution load in dye waste water, *Clean Technologies and Environmental Policy*, **14(4)**, 565-572.

Rasoulifard, M.H., H.H. Monfared, and S. Masoudian, (2011), Photo-assisted Hetero-Fenton decolorization of azo dye from contaminated water by Fe-Si mixed oxide nanocomposite, *Environmental Technology*, **32(14)**, 1627-1635.

Lin, K.Y.A., et al., (2015), A magnetic fluid based on covalent-bonded nanoparticle organic hybrid materials (NOHMs) and its decolorization application in water, *Journal of Molecular Liquids*, **204**, 50-59.

Sancar, B. and O. Balci, (2013), Decolorization of different reactive dye wastewaters by O^{-3} and O^{-3}/ultrasound alternatives depending on different working parameters, *Textile Research Journal*, **83(6)**, 574-590.

Sayan, E. and M.E. Edecan, (2008), An optimization study using response surface methods on the decolorization of Reactive Blue 19 from aqueous solution by ultrasound, *Ultrasonics Sonochemistry*, **15(4)**, 530-538.

Voncina, D.B. and A. Majcen-Le-Marechal, (2003), Reactive dye decolorization using combined ultrasound/H_2O_2, *Dyes and Pigments*, **59(2)**, 173-179.

Wu, C.H., P.K.A. Hong, and M.Y. Jian, (2012), Decolorization of Reactive Red 2 in Fenton and Fenton-like systems: effects of ultrasound and ultraviolet irradiation, *Reaction Kinetics Mechanisms and Catalysis*, **106(1)**, 11-24.

Wu, J.N. and T.W. Wang, (2001), Effects of some water-quality and operating parameters on the decolorization of reactive dye solutions by ozone, *Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering*, **36(7)**, 1335-1347.

Zhang, H., et al., (2005), The use of ultrasound to enhance the decolorization of the CI Acid Orange 7 by zero-valent iron, *Dyes and Pigments*, **65(1)**, 39-43.

Preliminary Data on the Presence of Canl ın Dogs from Two Major Districts of Albania

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ABSTRACT

Canine leishmaniasis (CanL) is an endemic widespread disease in Mediterranean countries, including Albania. This parasitic infection represents a major veterinary and human health concern. However, the distribution of the disease in Albania is heterogeneous and not all districts have been equally studied and characterized. This work describes the situation of CanL in dogs from two main districts of Albania, Tirana and Durrësi. The survey was performed during 2024 throughout the districts. In total were collected 82 blood samples from suspected animals with CanL, 58 in Tirana and 38 in Durresi district. Blood samples were analyzed by performing IFAT test (serological immunofluorescence antibody test). From the laboratory evaluation resulted positive 17.2 % of dogs from Tirana and 20.5 % of dogs from Durrësi district. The results obtained from the study revealed that CanL is an endemic infection among dogs from two major districts of Albania. Further study is needed with the aim to have a clear map of CanL spread in Albania.

Keywords – Canine Leishmaniasis, District, IFAT Test.

INTRODUCTION

Canine leishmaniasis (CanL) is a parasitic zoonotic infection of dogs caused by the *Leishmania* spp. Dogs are considered the parasite’s primary reservoir host, and it may also infect humans [6], [14]. However, the parasite's presence has also been reported in other animals, such as cats, equids, and [9], [16]. The infection is transmitted through the bite of infected sandflies [8]. It is a disease considered neglected by the World Health Organization, with a wide geographic distribution and presence in more than 98 countries [5]. Worldwide, it is estimated that there are about 12 million infected people, with approximately 700,000 to 1 million new cases reported each year [2], [10], [7], [18], [5]. Balkan was leishmaniasis endemic region with the first CanL cases recorded at the beginning of the 20th century [12]. According to Vaselek [17], our country is one of the major Balcan countries with the highest Leishmaniasis prevalence. Based to the data collected through years in Albania [15], [3], [4], [13], further study is needed to complete the distribution map of the disease. So the aim of the current study is to detect the prevalence rate of CanL among dogs from Tirana and Durrësi district.

MATERIALS AND METHOD

The present study was held in two major districts of Albania,Tirana and Durrësi. The suspected dogs were sampled during 2024. A total of 82 dogs from Tirana (n=58) and Durrësi (n=24) district suspected with leishmaniasis were sampled in this study. First all individuals object of the study suspected with CanL were examined accurately by the veterinarian. After clinical evaluation peripheral blood samples from positive dogs were collected. Initially clinically positive dogs were subjects to Leishmania rapid test. Than refrigerated blood samples of positive dogs with Leishmania rapid test were immediately transported to the laboratory and sera was stored at -20 degree for further laboratory evaluation. The sera of positive dog were confirmed with IFAT (serological immunofluorescence antibody test) a confirmation test with a sensitivity (Se) of 96% and specificity (Sp) of 98%, which is similar to the ELISA. This technique is used as reference to validate and estimate canine leishmaniasis (CanL). The procedure of IFAT test is performed as follows: after the activation of the serum, the samples are distributed in microtiter plates and diluted from 1/40 to 1/5120. 20 μl of each dilution is placed in the circles of the slide containing the leishmania promastigotes. The slide is incubated for 30 minutes at 37ºC and rinsed with PBS. 20 μl of FITC conjugated with anti-immunoglobulin is added to each well and the slide is incubated again for 30 minutes at 37ºC and rinsed with PBS. The slides are read under a fluorescent microscope. The highest dilution showing fluorescent promastigotes is taken to be the antibody titer, leishmania titer values of 1:40 is considered negative and ≥ 1:160 positive.

RESULTS

The results of the study are given in the below Table and Figure (Tab.1 and Tab.2, Fig.1).

Table 1**.** Results of dogs sampled by districts

District	Checked	Positive	%	Coinfidence interval 95%
Tirana	58	10	*17.2*	9.6 to 28.9
Durrësi	24	5	*20.8*	9.2 to 40.5

Table 2. Positive and negative test results of sampled dogs according to districts

District	Test results		Total
	Positive	Negative	
Tirana	10	48	58
Durrës	5	19	24
Total	15	67	82

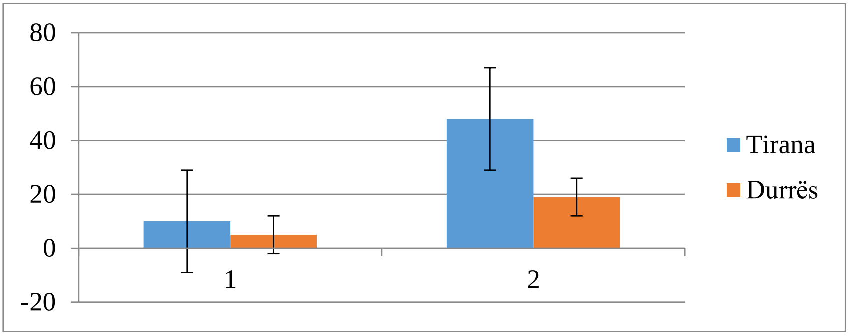

Fig.1. Comparison of CanL cases in dogs

There is no association between district and positive test results. Relative risk (RR = (10/58)/(5/24) = 0.82) and odds risk (OR = 10*19/5*48 =190/240 = 0.79) are lower than one, indicate that location is not a risk factor which affect the seroprevalence of leishmaniosis. The relationship between district and obtaining a positive leishmaniasis test result has been investigated using a chi-square test [1]. The strength of the association was assessed using the odds ratio and its 95% confidence intervals. The significance of association was assessed at a 5% level of significance, meaning that a p-value of less than 0.05 was deemed significant. Statulator, an online statistical tool, was used to perform the analyses [11]. According to the odds ratio 0.79, CI95% (0.24, 2.62), and chi-square value ($\chi^2 = 0.15$) indicate there is not association between district and positive leishmaniasis p-value (0.702) is not less than 0.05, the standard criteria for assessing p-values.

DISCUSSION

According to the results of the study the infection rate resulted to be higher in sampled dogs from Durrësi with 20.8 %, followed by Tirana with 17.2 % of positive cases. These preliminary data of the study sustain the presence of CanL in two major district of Albania with a high rate of infection. Further studies are needed in order to establish the presence of the disease in other areas of Albania.

CONCLUSION

The data collected from the sampled dogs of Tirana and Durrësi district shows clearly the presence of CanL. The prevalence of the disease resulted high. In order to have a clear geographical distribution of the CanL among dogs population, deeper studies are needed.

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REFERENCES

[1] A. Agresti (2012). Categorical Data Analysis (3rd ed.). Hoboken, New Jersey: John Wiley and Sons.

[2] B. Alemayehu, M. Alemayehu. Leishmaniasis: A Review on Parasite, Vector and Reservoir Host. *Health Sci. J*. vol.11, pp.1, 2017.

[3] B. Bizhga, D. Laci, G. Dhamo, R. Keci, K. Belegu, I. Bakiasi, L. Turmalaj. Survey for canine leishmaniosis. *J. Anim. Vet. Adv*, vol. 12, pp. 442–446, 2013.

[4] D. Hamel, E. Shukullari, Dh. Rapti, C. Silaghi, K. Pfister, S. Rehbein. Parasites and vector-borne pathogens in client-owned dogs in Albania. Blood pathogens and seroprevalences of parasitic and other infectious agents. *Parasitol Res*, 2016, vol.115, pp. 489–499.

[5] D.F. Vilas-Boas, E.K.N. Nakasone, A.A.M. Goncalves, D.F. Lair, D.S.D. Oliveira, D.F.S. Pereira, G.G. Silva, I.D.S.S. Conrado, L.A. Resende, LM.F. Zaldívar et al. Global Distribution of Canine Visceral Leishmaniasis and the Role of the Dog in the Epidemiology of the Disease. Pathogens, vol. 13, pp. 455, 2024

[6] G. Baneth, A.F. Koutinas, L. Solano-Gallego, P. Bourdeau, L. Ferrer, L. Canine leishmaniosis-new concepts and insights on anexpanding zoonosis: Part one. *Trends Parasitol.* vol.24, pp.324–330, 2008.

[7] J. Alvar, I.D. Vélez, C. Bern, M. Herrero, P. Desjeux, J. Cano, Jannin, M. den Boer. Leishmaniasis Worldwide and GlobalEstimates of Its Incidence. *Plos one*, vol.7, pp. 35671, 2012.

[8] M. Akhoundi, K. Kuhls, A. Cannet, J. Votýpka, P. Marty, P. Delaunay, D. Sereno, D. (2016). A historical overview of the classification, evolution, and dispersion of leishmania parasites and sandflies. PLoS Negl. Trop. Dis.

[9] M. Jiménez, E. González, I. Martín-Martín, S. Hernández, R. Molina. Could wild rabbits (*Oryctolagus cuniculus*) be reservoirsfor *Leishmania infantum* in the focus of Madrid, Spain? *Vet. Parasitol.* vol. 136, pp. 1915–1934, 2014.

[10] M. Rossi, N. Fa sel, N. How to Master the Host Immune System? Leishmania Parasites Have the Solutions! *Int. Immunol*, vol. 30, pp. 103–111, 2018.

[11] N.K. Dhand, M.S. Khatkar (2014). Statulator: An online calculator that conducts statistical analyses and interprets the results. Retrieved 22 November 2024 from http://statulator.com
[12] P. Tartalia. La Leishmaniose canine a split. Bul. Off. Intern. Hyg. Publ. XXIV, French, 1937.
[13] P. Qafezezi, A. Dingu, G. Dhamo, I. Dova, R. Postoli, X. Koleci, E. Ozuni and Dh. Rapti. Detection of canine leishmaniasis in dogs from Durrësi, Lezha and Shkodra district, Albania. Proceeding book, *5th* International Conference on Engineering and Applied Natural Sciences, Konoya, Turkey, 2024, pp. 444-447.
[14] R.J. Quinnell, O. Courtenay. Transmission, reservoir hosts and control of zoonotic visceral leishmaniasis. *Parasitology***,** vol.136, pp.1915–1934, 2009.
[15] T. Lazri, G. Duscher, R. Edelhofer, B. Bytyci, P. Gjino, A. Joachim. Arthropod-borne parasites of dogs, especially Leishmania, in the Kosovo and Albania. *Wien. Klin. Wochenschr*, 120, 54–58, 2008.
[16] T.D. Souza, A.P. Turchetti, R.T. Fujiwara, T.A. Paixão, R.L. Santos. Visceral leishmaniasis in zoo and wildlife. *Vet. Parasitol*, vol. 200, pp. 233–241, 2014.
[17] S. Vaselek. Canine leishmaniasis in Balkan – A review of occurrence and epidemiology. *Acta tropica*, vol.224, pp.106114, 2021.
[18] World Health Organization. Leishmaniasis. Available online https://www.who.int/news-room/fact-sheets/detail/Leishmaniasis (accessed on 25 March 2024).

Flood Management and Bridge Pier Designs: A Numerical Study of Dynamics in the Medjerda River

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ABSTRACT

Designing hydraulic structures such as bridges, dams, and irrigation canals necessitates thoroughly understanding associated hydraulic flow phenomena. Flow characteristics differ at various stages: before, during, and after passage through these structures. This study conducted a numerical analysis focusing on different geometries of obstacles in open channels to better understand the hydraulic jump following structure-fluid interaction.

Two geometric configurations of bridge piers (initially two, then three) were simulated using the finite volume method in Ansys-fluent. The objective was to assess how geometry affects flow characteristics under identical hydrodynamic conditions. Non-slip walls were assumed for all fluid-solid interaction surfaces, including piles, bed, and sidewalls. The study aimed to highlight pressures, velocity fields, and hydraulic properties derived from the modeling.

A comparative analysis of the numerical results for the two configurations evaluated the flow characteristics. The simulations provided a comprehensive understanding of water behavior, detailing the variability of the velocity field and the impact of water pressure on obstacles. This research offers valuable insights into developing effective river management strategies, improving our ability to mitigate risks, and enhancing environmental safety amid changing conditions.

Keywords – Hydraulic Leap; Flood Impact, Numerical Analysis; Finite Volume Method; Water-Structure Interactions.

INTRODUCTION

Throughout history, from ancient times to the present day, humans have maintained a profound connection with water, acknowledging it as a fundamental source of life for all living beings.

To manage effectively its use, humanity has consistently resorted to constructing civil engineering infrastructures to harness, cross, or utilize water from various watercourses [1].

This has entailed the development of dams, canals, aqueducts, and other structures that influence the natural flow of water and its hydraulic characteristics. Throughout history, civil and water resource engineers have played a critical role in advancing our understanding of water systems and designing efficient infrastructure for water management [2], [3].

Throughout history, bridges have served as vital connectors, their design evolving alongside advancements in geometry. From the simple structures of ancient civilizations to the remarkable geometric precision [4], the role of geometry in bridge design continued to expand. In medieval Europe, the creation of detailed stone bridge designs underscored the increasing focus on structural integrity [3], [4]. This evolution in bridge design became particularly crucial for managing flood risks, with the configuration of bridge piers playing a critical role in regions prone to flooding, like the Medjerda River basin. The Renaissance further solidified this synergy between geometry, bridge construction, and water management, influencing modern bridge designs [5].

While a substantial body of literature exists on flow-cylinder interaction, a knowledge gap persists concerning the hydrodynamic problem perspective [6]. Prior studies have primarily investigated the phenomenon from a kinematic standpoint, aiming to resolve the coherent flow structures (e.g., horseshoe vortices, down flow) generated around the cylinder by using point measurements and experimental observations [7]. However, these approaches often lack in-depth analysis of the underlying hydrodynamic forces and mechanisms governing the interaction [8], [9]. Consequently, the following research questions remain unaddressed:

- How does the number of piers affect the velocity distribution and control the backflow regions near to the structure?
- How does bed shear stress change depend on the number of piers?
- How does the number of bridge piers control the spatial distribution of the shear stress on the cylinders' surface and the bottom around them?

The primary object of this study is to find answers to these questions for this particular case and open new perspectives for water-obstacle comportment studies. The numerical model has enabled us to study the flow and scour processes, particularly concerning the issues referred to in the preceding paragraph.

METHODOLOGY

Describe in detail the materials and methods used when conducting the study. The citations you make from different sources must be given and referenced in references.

Domaine assumption

To enhance the relevance and value of our study, we chose to employ a real-scale case. The configuration of this type of bridge is frequently used in the Medjerda River in Tunisia and has been prevalent since the early 1980^{s} to the present [5].

A 250 m long by 20 m high and 80 m rectangular canal was used for the simulation. Figure 1 depicts the placement of the bridge, situated 50 meters from the entry of the channel.

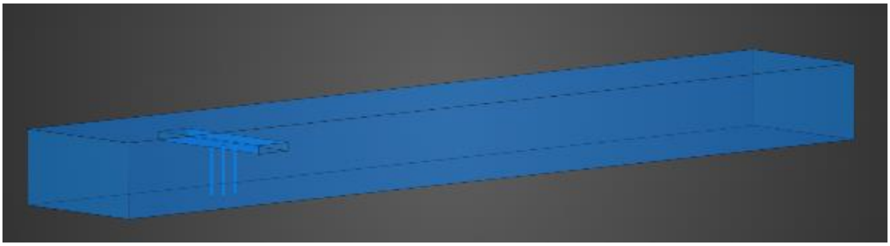


Fig. 1 - 3D Numerical Model of Bridge Pier Configuration within a channel

Governing equations

Monophasic turbulent flow Reynolds equations

In this section, a description of the computational model used throughout the present work provided the physical principles of conservation between pressure and velocity are described by the Navier-Stokes equations. These non-linear partial differential equations characterize the monophasic turbulent flow in an open channel at each point in the fluid [10], [11], [12]. The numerical solves the incompressible RANS equation:

$$\rho \frac{\partial \overline{u_i}}{\partial t} + \rho \overline{u_j} \frac{\partial \overline{u_i}}{\partial x_j} = -\frac{\partial \overline{p}}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\overline{\tau_{ij}} + \overline{\tau_{ij}{}'}\right) + \rho g_i \tag{1}$$

Where:

ρ: Fluid density

U : Longitudinal velocity vector

u_i: The component of the velocity vector in the I direction

t : Time

g_i: The component of the gravity vector in the I direction

μ: Viscosity

p: Static pressure

x_i: x component in the I direction

τ_{ij}: Tensor viscous stresses

$\overline{\tau_{ij}{}'}$: Reynolds stress tensor

The equation presented is the Navier-Stokes equation for fluid motion in its incompressible form. This equation describes the momentum balance in a fluid flow, accounting for various forces acting on a fluid particle [10], [13]. The first term represents the rate of change of momentum per unit volume of the fluid. The second term describes the convective transport of momentum, indicating how the fluid's momentum changes as it moves through space [14]. The third term represents the pressure gradient force per unit volume, highlighting the influence of pressure differences within the fluid [12], [15]. The fourth term accounts for the viscous stresses and Reynolds stresses in the fluid, incorporating both the internal friction due to fluid viscosity and the turbulent fluctuations [15]. Finally, the last term represents the gravitational force per unit volume, reflecting the effect of gravity on the fluid.

In summary, the Navier-Stokes equation balances the inertial forces, pressure forces, viscous forces, and gravitational forces acting on a fluid element.

The introduction of the Reynolds stress tensor leads to nonlinear terms in the equation, hence the need for a closure model. This model helps to represent the complex interactions between different components of turbulence and to estimate their overall effect on the mean flow. The Boussinesq hypothesis aids in resolving the closure issue by introducing Reynolds stresses, which make the equation system more adaptable and describe how turbulence affects the evolution of the mean flow [14], [15].

$$-(\rho\overline{u_i u_j}) = \mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) + \frac{2}{3}(\rho k)\delta_{ij} \quad (2)$$

There are many closure models available, but we have chosen to use the RSM closure model for our case. This decision is based on its extensive use in similar situations and its proven effectiveness in the literature [11].

To resume, before the numerical methods application, the Navier–Stokes equations are time-averaged (or ensemble-averaged in flows with time-dependent boundary conditions). Extra terms appear in the time-averaged (or Reynolds-averaged) flow equations due to the interactions between various turbulent fluctuations. This extra term is modeled with classical turbulence models. The K-omega was chosen after numerical validation and bibliographic research. For the ANSYS Fluent setup, we used the "Double Precision" option in 2D, incorporating gravitational acceleration, and the standard k-omega model.

Biphasic turbulent flow Reynolds equations

The Eulerian formulation of the Navier-Stokes incompressible equation for a non-miscible biphasic flow requires a numerical solution to determine the position of the interface between different fluid streams [8, 10], [11]. The interface capture method involves identifying the free surface within a fixed mesh in the domain containing the free interface. This approach differs from methods that track the deformations of the mesh's free surface [12]. The main advantage of these capture techniques is their ability to model flows with interface reconnections [11]. In this context, the technical method used to address the topological evolution of a biphasic region is the volume of fluid (VOF) approach, initially proposed by Hirt and Nichols. The continuity equation for phase q is derived from the following relations.

$$div(c_q \rho_q v_q) = \sum_{p=1}^{2} m_{pq} \qquad (3)$$

Where m_{pq} represents the mass transfer of the p^{th} phase at a q^{th} phase: $m_{12} = m_{21}$ and $m_{pp} = 0$. m_{pq} is the volume mass of the phase q and □q is the volume. The equation for the conservation of momentum during phase q is given by the following relation:

$$div(c_q \rho_q \vec{v}_q \vec{v}_q) = -c_q \overrightarrow{grad} p + div\overline{\tau_q} + \sum_{p=1}^{2}(\overrightarrow{R_{pq}} + m_{pq} + \overrightarrow{v_{pq}}) + c_q \rho_q (\overrightarrow{F_q} + \overrightarrow{F_{VMq}}) \qquad (4)$$

Where :

$\overline{\tau}$:	Shear stress of q^{th} phase (pa);
$\overrightarrow{F_q}$:	Exterior force of volume (N/kg);
$\overrightarrow{F_{VMq}}$:	Added mass force (N/kg);
$\overrightarrow{R_{pq}}$:	Interaction force at the interface;
c_q:	Void fraction of phase q;

Numerical Algorithm

The generation of mesh geometry by a pre-processor marks the transition from the physical realm to the numerical domain. Once created, this mesh is imported into computational code to iteratively solve equations and determine the parameters at each mesh node. The governing equations and turbulence model were resolved using a segregated solution approach, while the control volume technique was used to discretize the governing equations.

The SIMPLE (Semi-Implicit Method for Pressure-linked Linked Equations) method was utilized to simulate the velocity-pressure coupling within a multiphase model (VOF). To model the convective and diffusive terms, a second-order upwind method was applied.

The rise of relative residuals in each governing equation was tracked, with a convergence criterion of 0.001% to confirm the convergence of the numerical calculation. Relaxation coefficients for velocity, pressure, and other parameters were used to ensure the stability of the iterative process. The effects of friction near the wall were considered using the Standard Wall-Functions. Three different mesh distributions were analyzed to ensure grid-independent results, a crucial step for simulation accuracy and reliability. Using Fluent Mesh, we tested coarse, intermediate, and fine distributions. The coarse mesh, with fewer cells, allowed faster but less precise calculations. The intermediate mesh balanced resolution and computational time, capturing better gradients without excessive load. The fine mesh, with the highest resolution, provided maximum accuracy at the cost of longer computation. Comparing results from these meshes confirmed solution convergence, ensuring differences became negligible with finer meshes. This validated the independence of results from the mesh used, enabling the selection of the optimal balance of precision and efficiency.

RESULTS AND DISCUSSIONS

In previous sections, we introduced our study's framework and extensively developed our prototype using CFD simulations. This section unveils primary outcomes from geometric and numerical simulations, highlighting the imperative for a more in-depth investigation of the problem.

Mesh geometry generating

The mesh geometry was generated with specific settings to ensure accuracy and efficiency. Adaptive sizing was not utilized, with the growth rate set to the default value of 1.2 and a maximum element size of 4 m. Mesh defeaturing was enabled, using a defeature size of 1 cm to simplify small features. Curvature capture was activated, with the minimum curvature size set to 2.2 e-002 m and the curvature normal angle set to 18°. The bounding box diagonal measured 253.82 m, the average surface area was 2420.6 m^2, and the minimum edge length was 2.0 cm.

In terms of quality, no automatic inflation was applied. Instead, a smooth transition inflation option was selected, with a transition ratio of 0.272, a maximum of 5 layers, and a growth rate of 1.2. The pre-inflation algorithm was used to enhance the mesh quality near boundaries. The final mesh consisted of 65,748 nodes and 346,389 elements, ensuring a detailed and accurate representation of the geometry.

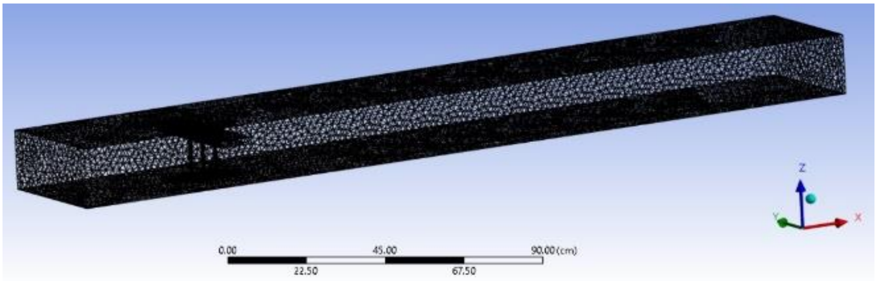


Fig. 2 - Grid configuration and mesh outcome

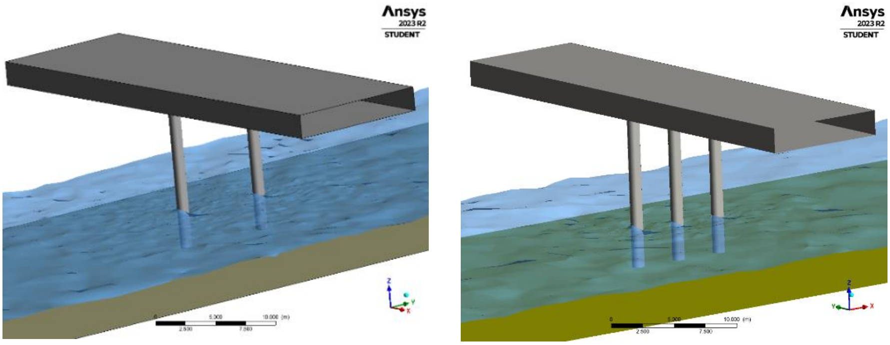
The mesh geometry was generated to accurately represent the riverbed and the configurations of the bridge piers. For the double piers configuration, two cylindrical piers were positioned symmetrically in the river. The mesh included finer elements around the piers to capture detailed flow patterns and turbulence. In contrast, the triple piers configuration involved an additional cylindrical pier, increasing the complexity of the mesh. This required further refinement to accurately simulate the increased turbulence and interactions between the piers, particularly in the regions where flow separation and recirculation occur.

Near the scours, where there is a significant velocity gradient, the mesh is uniformly very fine. The grid distribution affects both the amount of time required for calculation as well as how many iterations must occur for a given solution to converge.

Discussion of the velocity field

In the double piers configuration (figure 3. a), the velocity field showed moderate deviations around the piers. The flow maintained a relatively smooth pattern, with slight accelerations were observed in the recirculation zones behind the piers. In contrast, the water surface in the second configuration (figure 3. b) was significantly more disturbed compared to the two-pier setup.

Visible waves and elevated water levels are observed around each pier, particularly in the areas between the piers, indicating heightened turbulence and flow disruption.

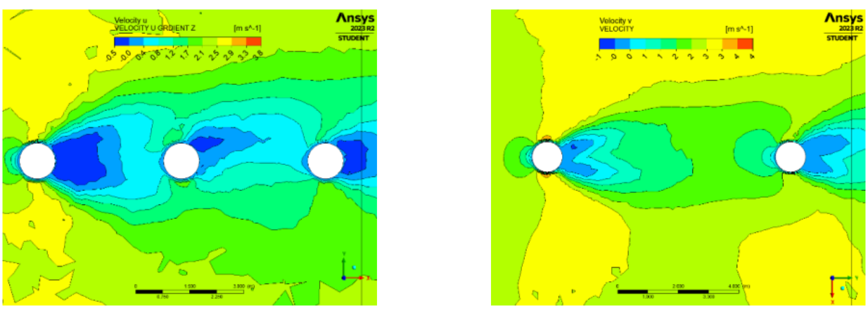


a) Two piers configuration bridge　　b) Three piers configuration bridge

Fig. 3 - Water Surface Behavior around Bridge Pier Configuration

The Navier-Stokes equations, which govern fluid flow, explain these observations through the balance of inertial and viscous forces. The presence of the piers disrupts the flow, causing local accelerations (due to reduced cross-sectional area) and decelerations (due to flow separation).

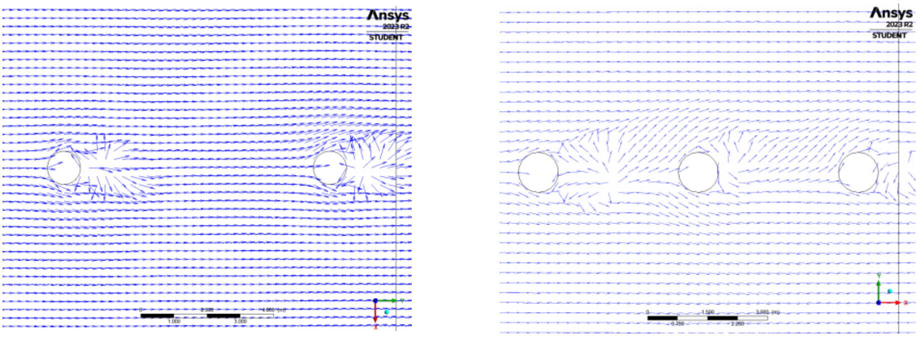
The double piers configuration (in Figure 4. a) displayed recirculation zones behind the piers, with water velocities generally lower in these areas due to the flow separation. The velocities in these recirculation zones were approximately 20% lower than the free stream velocity, resulting in smoother flow patterns and so with lower turbulence. The impact on the overall flow dynamics was relatively moderate, allowing the river to maintain its general flow direction with minimal disturbance.



a) Two piers configuration bridge　　b) Three piers configuration bridge

Fig. 4 - Contour of X-direction velocities differences between the two piers Two piers configuration bridge (a), and the three piers configuration bridge (b)

In contrast, the triple piers configuration (in Figure 4. b) exhibited significant deflections and higher turbulence in the velocity field. The flow became uneven, with pronounced accelerations and decelerations around the piers. The continuity equation (conservation of mass) requires that the same volume of water flows past each cross-section of the river. With three piers, the available space for the water to flow through is reduced, leading to higher velocities and more intense recirculation zones. The image provided (Figure 5) illustrates the velocity vectors near the water surface around circular bridge piers. In the double piers configuration (figure 5.a), the velocity vectors showed moderate deviations, with velocities increasing around the piers due to the constriction of the flow path. However, the increase was relatively modest, around 15% above the free stream velocity. In the recirculation zones behind the piers, the velocities were reduced by approximately 20%, indicating the formation of mild vortices and reduced turbulence.



a) Two piers configuration bridge b) Three piers configuration bridge

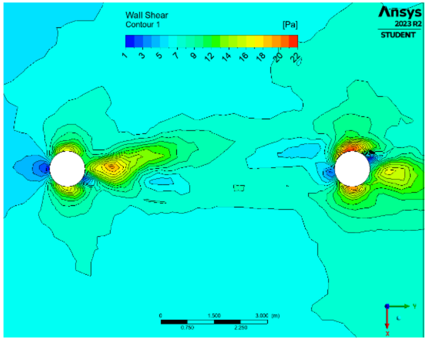
Fig 5 - X-direction velocity vectors differences between the two piers Two piers configuration bridge (a), and the three piers configuration bridge (b)

In the triple piers configuration (figure 5. b), the velocity vectors revealed more substantial deviations. The flow experienced significant accelerations, with velocities increasing by up to 35% above the free stream velocity around the piers. The recirculation zones were more extensive and pronounced, with velocities reduced by up to 30%, indicating stronger vortex formation and higher turbulence. The presence of an additional pier introduced more complexity and interaction between the recirculation zones, leading to a broader impact on the water flow dynamics.

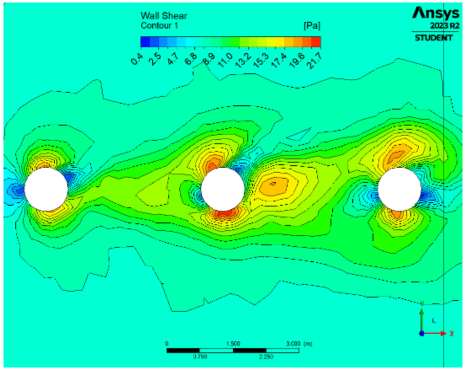
Discussion of the wall shear field

For the double piers configuration (figure 6. a), the wall shear field demonstrated moderate shear stress around the piers (between 15 to 21 Pa). The shear stress, τ, is a function of the velocity gradient near the wall, as described by the equation $\tau = \mu\,(\partial u/\partial y)$, where μ is the fluid dynamic viscosity, u is the velocity, and y is the distance from the wall. The double piers create moderate gradients, leading to manageable levels of shear stress.

In the triple piers configuration, the wall shear field showed increased shear stress, particularly between and downstream of the piers. The higher shear stress can be attributed to the increased velocity gradients caused by the more complex flow patterns and the interactions between the piers. The triple configuration introduces more regions where the flow velocity changes rapidly, leading to higher shear forces acting on the riverbed and the piers themselves. This suggests a more significant impact on sediment transport and potential erosion around the piers, as the increased shear stress can mobilize more sediment particles.



a) Two piers configuration bridge



b) Three piers configuration bridge

Fig. 6 - Shear stress (Pa) at the bottom for the two piers configuration bridge (a), and the three piers configuration bridge (b)

CONCLUSIONS

This study highlights the significant influence of bridge pier configurations on water flow patterns, velocity fields, and wall shear stress in river systems. Through detailed numerical simulations, it was found that the triple piers configuration induces more pronounced disturbances and higher shear stress compared to the double piers' setup. These findings align with fluid dynamics principles, as illustrated by the Navier-Stokes and continuity equations.

The addition of a pier in the triple configuration reduces the effective flow area, leading to increased velocities and more intense recirculation zones. This creates larger velocity gradients near the piers, resulting in higher shear stresses. Specifically, in the double piers' configuration, about 30% of the surface exhibits shear stress values above the threshold of 17 Pa, whereas in the triple piers' configuration, this value rises to approximately 50%. This significant increase in the shear stress suggests a higher potential for erosion and sediment transport around the piers.

These findings have crucial implications for bridge design and flood management. The double piers configuration, with its lower impact on water flow and sediment transport, may be preferable in scenarios where minimizing environmental disruption is essential. On the other hand, the triple piers configuration, while potentially offering greater structural stability, requires careful consideration of its environmental impact, particularly regarding increased shear stress and potential erosion.

Future research should focus on experimentally validating these numerical results through laboratory and field studies. Additionally, advanced modeling techniques incorporating real-time data will enhance understanding of the interactions between bridge structures and water flow. By integrating these insights into the design process, innovative solutions that balance the infrastructure need with the environmental sustainability can be developed.

Collaboration among researchers, engineers, and policymakers is essential to advance hydraulic engineering. By working together, safer and more resilient bridge designs that harmonize with natural water dynamics can be developed, effectively mitigating flood risks and minimizing environmental disruption. This study lays the foundation for such collaborative efforts, emphasizing the importance of considering both structural and environmental factors in bridge design.

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REFERENCES

[1] Linton, J. (2014). Modern water and its discontents: a history of hydrological renewal. Wiley Interdisciplinary Reviews: Water, 1(1), 111-120. https://doi.org/10.1002/wat2.1009

[2] Charlesworth, S. M., Fontaneda, L. A. S., & Mays, L. W. (2016). Back to the future? History and contemporary application of sustainable drainage techniques. Sustainable Surface Water Management: A Handbook for SuDS, 11-30. https://doi.org/10.1002/9781118897690.ch2

[3] Gleick, P. (1998). The world's water. Issues in Science and Technology, 14(4), 80-88.

[4] Hunter, N.M., Bates, P.D., Neelz, S., Pender, G., Villanueva, I., Wright, N.G. and Mason, D.C. (2008) Benchmarking 2D Hydraulic Models for Urban Flooding. Proceedings of the Institution of Civil Engineers-Water Management, 161, 13-30. https://doi.org/10.1680/wama.2008.161.1.13

[5] Mahjoub, Y., Soualmia, A. and Kourta, A. (2024) Bridge Impact on Water Behavior: Simulation- Application to the Medjerda River in Tunisia. Open Access Library Journal, 11: e11597. https://doi.org/10.4236/oalib.1111597

[6] Zdravkovich, M. M. (1997). Flow around circular cylinders: Volume 2: Applications (Vol. 2). Oxford University Press.

[7] C, Sumer BM, Fuhrman DR, Jacobsen NG, Fredsøe J. 2015 Numerical investigation of flow and scour around a vertical circular cylinder. Phil. Trans. R. Soc. A 373: 20140104. http://dx.doi.org/10.1098/rsta.2014.0104

[8] Jasim, R. A., Hussen, W. Q., Abdullah, M. F., & Zulkifli, R. (2023). Numerical Simulation of Characterization of Hydraulic Jump Over an Obstacle in an Open Channel Flow. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 106(1), 1-15. https://doi.org/10.37934/arfmts.106.1.115

[9] Patil, D., Jadhav, R., & Sohoni, P. Analysis of Different Shapes in Bridge Pier Subjected to Extreme Flood Loading. National Conference on Structural Engineering NCRASE – 2020 https://www.researchgate.net/publication/347933498

[10] Nasim, M., Setunge, S., Zhou, S., & Mohseni, H. (2018). An investigation of water-flow pressure distribution on bridge piers under flood loading. Structure and Infrastructure Engineering, 15(2), 219–229. https://doi.org/10.1080/15732479.2018.1545792

[11] Baykal C, Sumer BM, Fuhrman DR, Jacobsen NG, Fredsoe J. 2015 Numerical investigation of flow and scour around a vertical circular cylinder. Phil. Trans. R. Soc. A 373: 20140104. http://dx.doi.org/10.1098/rsta.2014.0104

[12] Aksel, M. (2023) Numerical Analysis of the Flow Structure around Inclined Solid Cylinder and Its Effect on Bed Shear Stress Distribution. Journal of Applied Fluid Mechanics, 16, 1627-1639. https://doi.org/10.47176/jafm.16.08.1697

[13] Roulund, A., Sumer, B.M., Fredsøe, J. and Michelsen, J. (2005). Numerical and Experimental Investigation of Flow and Scour around a Circular Pile. Journal of Fluid Mechanics, 534, 351-401. https://doi.org/10.1017/S0022112005004507

[14] Tartandyo, R.A., Ginting, B.M. and Zulfan, J. (2023) Scale Effects Investigation in Physical Modeling of Recirculating Shallow Flow Using Large Eddy Simulation Technique. Journal of Applied Fluid Mechanics, 17, 43-59. https://doi.org/10.47176/jafm.17.1.1980

[15] Talbi, S. H., Soualmia, A., Cassan, L. and Masbernat, L. (2016) Study of Free Surface Flows in Rectangular Channel over Rough Beds. Journal of Applied Fluid Mechanics, 9, 3023-3031. https://doi.org/10.29252/jafm.09.06.25898

From Soil to Roots: The Critical Interactions Driving Plant Nutrition

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ABSTRACT

Ecosystems are balanced and complementary. Soil properties significantly affect plant nutrient uptake and growth, shaping agricultural productivity and ecosystem health. This review brings together recent research on the impact of specific soil properties (soil texture, structure, organic matter, pH, moisture, and salinity) on plant growth. Soil texture affects water retention, drainage, and nutrient availability. Clay soils, with high cation exchange capacity, provide more excellent nutrient retention but may pose challenges for root penetration. Conversely, sandy soils facilitate root growth but often require more frequent fertilization. Soil organic matter enhances nutrient availability, water retention, and soil structure, with humus playing a critical role in maintaining soil fertility. Soil pH affects nutrient solubility and microbial activity, with most plants thriving in slightly acidic to neutral conditions. Nutrient uptake and root development can be impaired if the pH is at extreme levels. Soil moisture is critical for dissolving nutrients and supporting physiological processes such as photosynthesis and transpiration. However, excess moisture can reduce soil aeration, hindering root respiration. Soil salinity, characterized by high concentrations of soluble salts, creates osmotic stress, reducing water and nutrient uptake and potentially causing ionic toxicity. Understanding these soil properties and their interactions with plant physiology is essential to optimize soil management practices. This review highlights the need for integrated soil management strategies that consider the complex interaction between physical, chemical, and biological factors to promote plant growth and agricultural sustainability.

Keywords – High-Affinity, Nutrient Uptake, Organic Matter, Root System, Soil And Plant Interaction, Soil Properties.

INTRODUCTION

Soil is composed of a mix of mineral and organic particles that vary in size and composition, significantly influencing plant growth. The spaces between these particles, known as pore spaces, hold water and air, facilitating their movement through the soil. These pores also provide pathways for small animals and promote root extension and growth. Anchored in the soil, roots support plants structurally and absorb essential water and nutrients (Foth, 1991).

Plant root systems play a crucial role in absorbing water and nutrients from the soil to sustain growth and development. However, roots inherently lack the capacity to detect water and nutrients independently. To overcome this, they form symbiotic relationships with soil mycorrhizal fungi, which significantly enhance their growth potential. As a result, plant development is heavily influenced by soil quality, with each species exhibiting unique responses and tolerance levels to varying conditions (Khalil et al., 2015).

Plant nutrition governs the dynamic interaction between soil nutrients and plant growth. For nutrients to benefit plants, they must first be transported to the roots and absorbed in usable forms. Each nutrient plays an essential role in physiological processes critical for healthy development, and any deficiency can manifest as distinct symptoms(Fageria & Moreira, 2011).

Plant-soil interactions are crucial for nutrient cycling, soil structure, and microbial diversity (Baldi, 2021; Faucon, 2020). Plants absorb nutrients and water, stabilize soil, and contribute organic matter, enhance soil fertility and carbon sequestration. Root exudates support beneficial microbes, aiding nutrient uptake and disease suppression. These interactions regulate water cycles, improve soil health, and support biodiversity, ensuring ecosystem resilience and productivity (Alam, 1999).

Soil properties play a pivotal role in determining plant growth. Key factors include soil texture, structure, pH, and organic matter content. For instance, sandy soils, characterized by large particles, provide excellent drainage but often struggle with nutrient retention. In contrast, clay soils retain water and nutrients well but may suffer from poor aeration (Ge et al., 2019). Soil pH also influences nutrient availability, with most plants thriving in a slightly acidic to neutral pH range of 5.5 to 7.5 (Gilmour, 1983). Additionally, high organic matter content enhances soil structure, boosts water retention, and improves nutrient supply. Soil compaction reduces root penetration and water infiltration, hindering growth (Yu et al., 2024). Properly balanced soil conditions promote robust root systems, efficient nutrient uptake, and healthy plant development (Rasmussen & Schmidt, 2022). Understanding and managing these characteristics can optimize soil health and plant productivity.

The main objectives of this Review paper are: 1) Describe the root anatomy and the relationships between the root system, 2) How nutrients get to the root and the process of nutrient uptake, and 3) Effect of some soil characteristics on plant minerals uptake and plant growth.

PLANT ROOT SYSTEM

Roots are vital to plants, performing essential roles such as absorbing water and minerals from the soil and providing stability by anchoring the plant. Additionally, they serve as reservoirs for storing food and nutrients. Many plant roots also form symbiotic partnerships with soil microorganisms, which facilitate the decomposition of organic matter and the recycling of nutrients, contributing to plant health and growth. The fact that shoots do not grow in the dark and roots continue to grow regardless of light conditions further emphasizes the importance of roots. For the plant as a whole, roots are vital. By storing energy and providing support, they help the plant to survive. Roots can relieve environmental stress on the above-ground parts of the plant. They can also help prevent soil erosion. Depending on the plant species, root systems can be relatively shallow or extremely deep. Taproots can grow to depths of more than 10 meters, and some roots can reach 2-3 times the height of the plant. An example of a plant with an intense root system is the cup plant, Silphium perfoliatum. It is known to have roots that reach more than 4.5 meters deep. Roots can affect the human economy through agriculture, and it is claimed that analyzing roots can determine the potential yield of a crop. Root systems are so important to plant health that most plants cannot survive without a fully functional root system (Fazeli-Nasab, Piri, & Rahmani, 2022; Francis, Aravindakumar, Brewer, & Simon, 2023; Pattnaik, Mohapatra, & Gupta, 2021; Tomaszewska-Sowa & Figas, 2011).

Root Anatomy

Plant roots are crucial for growth, as they extract water and nutrients from the soil and, in some cases, serve as storage for essential reserves (Wasaya, Zhang, Fang, & Yan, 2018). Their main components of root anatomy:

1. Root Cap: Located at the tip of the root, the root cap is a protective structure composed of dead cells. It helps the root navigate through the soil by sensing gravity and obstacles. The root cap considers environmental factors and protects the root apical meristem. (Shi et al., 2018).

2. Meristem: Found behind the root cap, the apical meristem is a region of actively dividing cells responsible for root growth in length. It gives rise to the primary tissues of the root. Because of their capacity for self-replication, meristem cells are often referred to as stem cells (Kerk & Sussex, 2001).

3. Primary Tissues:

• Epidermis: The root's epidermis is also known as the piliferous layer or epiblema. the protective outermost layer of cells covers the root. It is responsible for absorbing water and nutrients from the soil and produces root hairs to enhance the surface area for efficient absorption (Staňová et al., 2012).

• Cortex: Positioned between the epidermis and the vascular cylinder, the cortex is composed of parenchyma cells. It functions as a key region for storing and transporting water and nutrients within the root (Soper, 1959).

• Endodermis: A single layer of cells surrounding the vascular cylinder. It regulates the passage of water and ions into the vascular tissue through a specialized structure called the Casparian strip. Figure (1)

• Pericycle: Located just inside the endodermis, the pericycle is a layer of cells from which lateral roots originate. It also plays a role in secondary growth in roots (Beeckman & De Smet, 2014).

4. Vascular Cylinder (Stele): The central region of the root containing vascular tissues responsible for transporting water, nutrients, and sugars. It consists of:

• Xylem: Responsible for transporting water and dissolved minerals absorbed by the roots to other parts of the plant.

• Phloem: Facilitates the movement of sugars and other organic compounds, produced during photosynthesis in the leaves, to different regions of the plant for use or storage (Fahn, 1982).

5. Lateral Roots: Branches originating from the pericycle and extending horizontally from the primary root. They help increase the root system's surface area for absorption and anchorage.

6. Root Hair Zone: The root region where root hairs are present. Root hairs are tiny projections of epidermal cells that significantly increase the surface area to absorb water and nutrients (J. P. Lynch et al., 2021).

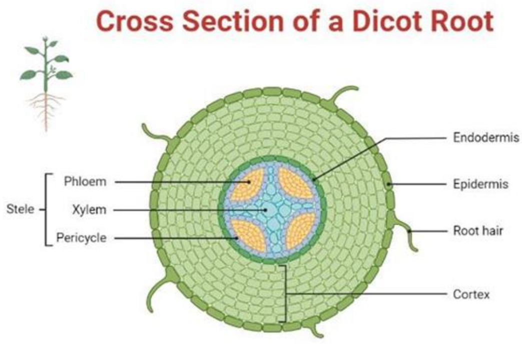

Figure 1: Cross section of a dicot root.

Root Systems

Plants have two basic types of root systems: taproot and fibrous. Both are illustrated in the Figure below.

1. Tap root system: The tap root system consists of a main primary root that extends vertically downward, with numerous smaller lateral roots branching out from it. That develops from the radicle and continues as the primary root, giving off lateral roots (Klepper, 1992). These supply strong anchorage as they can reach deep into the soil. It is the central root system of dicots. Taproots are generally found in beetroots, sugar beet, carrot, parsley, radish, and trees such as elms, oaks, and pines.

2. Fibrous root system: A root system characterized by numerous slender branches of similar length, creating a fine and uniform network. (Rost, Barbour, Stocking, & Murphy, 1998). A mass of slender, fiber-like roots arises from the base of the radicle and plumule, constituting the fibrous root system (figure 2). When dragged, bring with them a massive clump of soil; this happens because the fibrous root of these plants consists of several primary roots that branch to form a heavy mass. Commonly, they do not penetrate the soil very deeply. Plants with fibrous root systems are especially useful in preventing soil erosion because their roots attach firmly to soil particles. The fibrous root system is the central root system of monocots, e.g., grass, maize, and wheat.

In addition to these two main types, there are other specialized types of roots:(Eshel & Beeckman, 2013; Zierer, Rüscher, Sonnewald, & Sonnewald, 2021) :

Tuberous roots: These roots help store large and essential amounts of nutrients to help feed the plant as a whole. These roots are modified from stems and are fleshy and enlarged storage organs.

Water roots: This type of root spreads where plants grow in water. These roots differ from the usual roots that grow in the soil morphologically and are more fragile and thinner than others.

Creeping roots are shallow roots that do not penetrate the soil and spread horizontally over long distances. These roots are found in many trees.

Parasitic roots, or historia, are specialized structures that penetrate the host plant's tissue and extract water and nutrients. This is why parasitic plants can survive without producing food through photosynthesis.

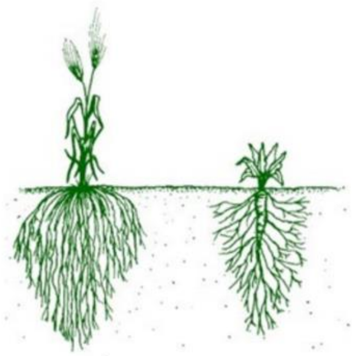

Figure 2: Root types (Left: Corn's fibrous root system. Right: Carrot's taproot system).

Root Function

The functions of root systems are generally divided into five main roles: plant anchorage, resource uptake, resource storage, and environmental sensing and modification.

Anchorage: The primary function of roots is to anchor the plant in the soil, allowing the other functions to occur. The role of the mechanical root in stabilizing the plant in the soil has been studied extensively in recent years because of its importance and impact on other root functions (Boyce, 2005; Eshel & Beeckman, 2013; Zhang et al., 2023).

Plants are generally exposed to several types of external forces that affect their stability in the soil, the most important of which are herbivore grazing and wind. The wind force is considered a lateral pushing force, while the other is a vertical pulling force (Ennos & Pellerin, 2000; S. Liu, Ji, & Zhang, 2022).

If the plant is exposed to external forces that reduce its stability in the soil, this harms the productivity and quality of crops. It can also cause the plant to die because it cannot extract the water and nutrients it needs (J. Zhu, Leung, & Wang, 2023).

Understanding the mechanism of plant stability in the soil is very important to mitigate the mechanical failures that can occur in the natural environment. These malfunctions appear in the form of uprooting or failure of the stem or root. In light of this, researchers delved into the study of the biomechanics of root consolidation through various methods, including the process of mechanical extraction combined with pressure recordings (Somerville, 1979; Valladares & Niinemets, 2007)

These studies concluded that the resistance of plants to the wind depends on two essential factors: the ability of the lateral roots facing the wind to withstand bending force and the ability of the sinkers and tap roots facing the wind to uproot. In Crook and Ennos (1996) study of deep-rooted pine, he found that approximately 25% of the tree's stabilization support was provided by the side wind, while the remaining 75% was attributable to the tap roots, sinking downwind.

Resource uptake: Resource uptake occurs through the complementary functions of leaves and roots. Leaves supply the plant with carbon and energy through photosynthesis, while roots absorb water and essential nutrients to meet the plant's nutritional requirements.

One of the key mechanisms in plant nutrition is nutrient absorption, which primarily occurs in ionic form following the hydrolysis of dissolved salts in the nutrient solution. The active root is the primary organ responsible for this process. Nutrients, whether anionic or cationic, are absorbed from the solution, and their uptake triggers the release of protons or hydroxyl ions within the plant to maintain electrical charge balance. This ionic balance is crucial but can also lead to shifts in the solution's pH, depending on the type and amount of substances absorbed. (Pugnaire & Valladares, 2007; Tang & Rengel, 2003).

Plants access soil resources through mechanisms like root interception, diffusion, and the movement of water and nutrients via mass flow. In root interception, growing roots push through the soil, interacting with soil particles and colloids. As a result, roots take up water and essential nutrients directly from the soil environment. This method generally contributes to over 10% of the total nutrient intake by the roots.

Mass flow is the movement of nutrients dissolved in water to the roots. The main driver of this process is plant transpiration. This process is responsible for the transfer of nitrate, sulfate, calcium, and magnesium.

Diffusion is the process by which nutrients move from regions of higher concentration to areas with lower concentration. Therefore, nutrients are transferred from the soil to the roots until the concentration ratios of nutrients reach equilibrium. Providing nutrients through diffusion is especially important for transporting phosphorus and potassium.

Diffusion and efflux provide the plant with NPK, work in concert, and cannot be separated in the field. Water passively moves in and out of the roots based on the soil-plant system's water potential gradient. The path of nutrients to the root may be passive (no energy required) or active (energy required) (NRCCA, 2010; Pugnaire & Valladares, 2007).

The competitiveness of plants below the soil surface is closely linked to the size and efficiency of their root systems. Research indicates that larger and more efficient root systems, capable of occupying greater soil volumes, tend to enhance a plant's competitive advantage (Aerts, Boot, & Van der Aart, 1991; Casper & Jackson, 1997).

Plant roots can grow more densely to expand the area of soil they explore, allowing them to access greater amounts of water and nutrients. In many cases, roots grow abundantly in the presence of a plant with high fertility in terms of water and nutrients. The propagating roots are usually small in diameter but high in density (Berendse, de Kroon, & Braakhekke, 2007; De Willigen, Nielsen, Claassen, & Castrignanò, 2000; Duncan & Ohlrogge, 1958).

Resource Storage: Most plants develop either a fibrous root system, a taproot system, or a combination of both, with the latter being the most common. However, some plants have roots with adaptations adapted to perform specific functions and absorb water and minerals in solution (Stern, Bidlack, Jansky, & Uno, 2008).

Since the plant needs to adapt to changing environments, the function of the roots in storing nutrients and water is very important. When nutrients are abundant, the roots store carbohydrates and nutrients in addition to water to provide them during periods when the need is more significant than what is available. Roots play a crucial role in storage for many plant species, often serving as the primary site for accumulating resources. In some plants, roots swell to store significant quantities of starch and carbohydrates, which are later utilized during growth and development. Additionally, many species rely on modified underground stems, such as rhizomes, bulbs, corms, stem tubers, lignified tubers, and nodes, as specialized structures for storage (De Kroon & Bobbink, 1997).

In the case of perennial herbaceous plants, especially those that live in seasonal environments, they depend on underground reserves. Woody plants, especially in environments susceptible to fires, naturally rely on roots to store carbohydrates and other nutrients (Miyanishi & Kellman, 1986).

Roots serve as major storage sites for nutrients, with most research emphasizing carbon, nitrogen, and phosphorus. Starch is the primary form of carbon storage, while nitrogen is stored in forms such as storage proteins, amino acids, amides, or nitrates (Lewis, 1984; Staswick, 1994; Tromp, 1983). Phosphorus is typically stored as phosphate, phytic acid, or polyphosphate. Within the cell, sugars, phosphates, and nitrogen are primarily stored in the vacuole, while starch is stored in plastids. Parenchyma cells in the roots are the main tissues responsible for storage (Bieleski, 1973). Plant material storage can be categorized into two types: **accumulation storage** and **reserve storage**. Accumulation occurs when resource uptake exceeds the plant's immediate use capacity, resulting in surplus storage without competing with growth or maintenance. On the other hand, reserve storage involves resources that could otherwise be allocated for growth or maintenance. This type of storage has a significant cost, as it directly competes with developmental processes (Bell, Pate, & Dixon, 1996; Chapin III, Schulze, & Mooney, 1990; Loewus & Tanner, 2012; Willenbrink, 1982).

Environmental Sensing: Beyond their primary functions, roots play a critical role in sensing environmental conditions and relaying information about the coordination between root and shoot functions via hormones. Plants produce various hormones, including auxins, cytokinins, gibberellins, ethylene, and abscisic acid, which regulate growth and development. Roots are the main synthesis sites for two key hormones: cytokinins and abscisic acid. Cytokinins, produced in the roots, are transported to the leaves through the xylem, where they help delay leaf senescence and sustain metabolic activity. Cytokinins influence various plant processes, including cell division, morphology, protein synthesis, and the development of chlorophyll. Abscisic acid, on the other hand, is crucial for seed dormancy under unfavourable environmental conditions. It regulates water uptake in the seed's embryonic tissues to maintain dormancy. Additionally, abscisic acid helps prevent excessive water loss by controlling stomatal closure (Aiken & Smucker, 1996; Torrey, 1976).

Environmental Modification: We said earlier that roots can sense their environment, but not only that, they have the ability to modify that environment. Roots release organic molecules and water, collectively known as root exudates, into the surrounding soil. These secretions profoundly influence the physicochemical and biochemical properties of both the roots and the soil. They play a critical role in enhancing soil health and fostering the stability and productivity of terrestrial plant communities. Physically, they help promote healthy root growth by protecting the roots from drying out, stabilizing the root in the soil, and selectively absorbing and storing ions (Pugnaire & Valladares, 2007).

One example of the physical impact of root activity is hydraulic redistribution. In this process, plant roots act as conduits, transferring water from wetter soil regions to drier areas. This mechanism significantly influences soil water dynamics by enabling water movement across the soil matrix in ways that would not occur through gravity, preferential flow, or standard infiltration processes (Ryel, 2004).

NUTRIENT UPTAKE BY PLANT ROOTS

Plant nutrients

Macro and micronutrients are essential elements plants require for their growth and development, but they differ in quantity needed, role in plant physiology, and occurrence in plant tissues. Macronutrients, such as N, P, K, Ca, Mg, and S, are needed in large quantities and are essential for vital processes like photosynthesis and protein synthesis (Uchida, 2000). In contrast, micronutrients, including Fe, Mn, Zn, Cu, Mo, B, Cl, and Ni, are required in trace amounts. Despite their lower demand, these micronutrients play a crucial role in specific enzyme functions and metabolic pathways that support overall plant health and development (Rasmussen & Schmidt, 2022). Macronutrients are found in higher concentrations within plant tissues, whereas micronutrients are required only in trace amounts. However, both are equally vital for ensuring optimal plant growth and development. Deficiencies in either macro or micronutrients can lead to visible symptoms and negatively impact plant health and productivity (de Mello Prado & de Mello Prado, 2021).

Nutrient uptake

The process of nutrient uptake by plant roots is highly intricate and essential for maintaining plant health, growth, and productivity. Specialized structures such as root hairs and root tips play a key role by increasing the surface area for absorption and enabling efficient nutrient exchange (Mengel, 1995). Through active transport mechanisms, roots absorb essential nutrients, including NPK, and various micronutrients, from the soil solution. This involves the movement of ions across root cell membranes against a concentration gradient, which requires energy to sustain the process (Adler, Cumming, & Arora, 2009).

Effect of Soil Characteristics on Plant Minerals Uptake and Plant Growth

To understand how soil properties affect plant growth and nutrient uptake, we need to know about the root environment, known as the rhizosphere.

In 1904, Hiltner defined the rhizosphere as the area surrounding the plant root, inhabited by a unique group of microorganisms affected by the chemicals released from plant roots. This region does not have a fixed shape or size; its dimensions vary depending on the type and characteristics of the plant's root system. The rhizosphere is a narrow region of the soil, and according to Coleman, Cole, Hunt, and Klein (1977) study, the rhizosphere constitutes 2 to 3 percent of the total soil volume.

The plant rhizosphere represents a niche where important biogeophysical processes in ecosystem function occur. The rhizosphere has been divided into two zones (Endorizosphere and Ectorizosphere) depending on its proximity to the root, and these zones are shown in Figure (3).

The endorizosphere was first used in 1978 to refer to the inner part of the root that contains bacteria (Balandreau & Knowles, 1978). It is defined as a part of the root colonized by microbes that benefit from the organic compounds secreted by the root (Burns & Slater, 1982; Klepper, 1992; Walker, Bais, Grotewold, & Vivanco, 2003).

The ectorizosphere is formed by the soil particles surrounding the root (Lambers, Raven, Shaver, & Smith, 2008). According to some studies, it is considered part of the soil, not the root (Bashir et al., 2016; Brundrett, 2009; Lambers et al., 2008).

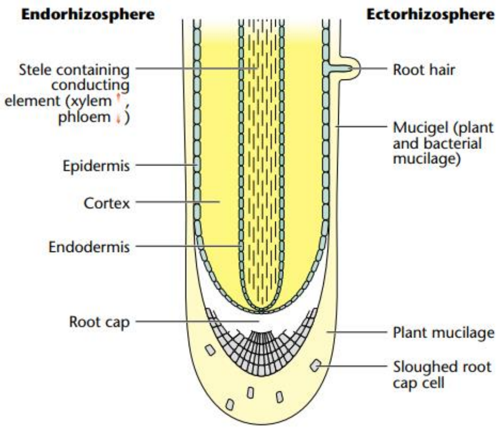

Figure 3: The rhizosphere zones (J. M. Lynch, Brimecombe, & De Leij, 2001).

Effect of Soil Texture and Structure

Soil texture

Soil texture describes the relative proportions of sand, silt, and clay particles within the soil. These particles differ in size and mineral composition, and their combination determines the overall texture. Soil texture plays a significant role in influencing plant growth and development by affecting water retention, drainage, aeration, and nutrient availability (Huntley, 2023).

Clay particles, the smallest of the soil components (< 0.002 mm), are highly fine and contribute significantly to soil properties. Compared to coarse-textured soils, clay soils generally offer greater nutrient availability. Their high cation exchange capacity (CEC), a result of their small particle size and large surface area, allows them to retain positively charged ions like calcium, magnesium, potassium, and ammonium, ensuring these nutrients are accessible to plants (Roy, Finck, Blair, & Tandon, 2006). While clay soils are often nutrient-rich, their compact nature can hinder root penetration and plant growth, requiring proper management to optimize their benefits.

Clay particles have an extensive surface area, offering abundant binding sites for nutrients, which contributes to the strong nutrient-holding capacity of fine-textured soils. Another factor is the net surface charge of clay particles, which allows them to attract and retain essential nutrients effectively (Jones & Jacobsen, 2005). Clay soils can become compacted, restricting root growth and exploration. Compaction can limit the ability of roots to access nutrients deeper in the soil profile.

Sand particles are the largest particles (at 2.0 to 0.05 mm) among the three soil components. Sandy soils have a lower CEC compared to clay soils. They typically have lower nutrient-holding capacity and may require more frequent fertilization to provide essential nutrients to plants. Nutrients can leach more readily from sandy soils due to their coarse texture and fast drainage (Jones & Jacobsen, 2005).

Sandy soils, characterized by their coarse texture, provide minimal resistance to root penetration, making it easier for roots to grow. However, their ability to retain water and nutrients, especially in the root zone, is often limited (Yu et al., 2024).

Silt particles are smaller than sand but larger than clay (0.05 to 0.002 mm) (Figure 4). Loamy silt soils typically have a balanced mixture of sand, silt, and clay particles, combining the benefits of each soil type. This balanced texture allows for good water retention, nutrient availability, and root penetration, supporting optimal plant growth.

Loamy soils have good water retention, drainage, aeration, and nutrient-holding capacity, making them ideal for most plants. They are often described as having a crumbly texture and are considered the best soil type for gardening and agriculture (Gatiboni, 2018).

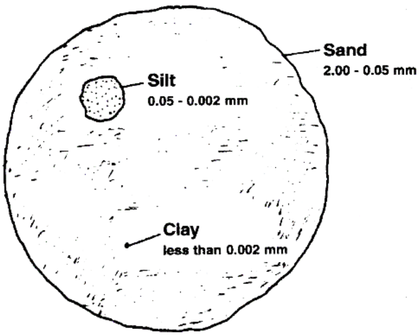

Figure 4: Relative sizes of separate soil particles

Soil structure

Soil structure refers to the arrangement and grouping of soil particles into aggregates or clumps. This organization affects the soil's porosity, drainage, aeration, and its ability to support plant growth. The structure is described in terms of; type (shape and arrangement), class (size), and grade (degree of aggregation). Soil structure is a crucial component of soil health, as it impacts key properties such as permeability, water retention, aeration, and nutrient availability, all of which are essential for healthy plant growth (Arunkumar, 2021).

The structure of soil significantly impacts the movement and availability of water, air, and nutrients, as well as the development of plant roots, which tend to be hindered in soils that are dry, compacted, or poorly aerated. Additionally, soil structure determines its resilience and stability against disturbances and erosion. It is also crucial for processes such as water infiltration, aeration, root growth, carbon sequestration, and nutrient recycling (Schroth & Sinclair, 2003).

Soil particles group together to form aggregates, which are held in place by binding forces from clay particles, organic matter, and cementation processes. The arrangement and size of these aggregates define the soil's structure. Well-structured soil supports diverse life forms, facilitates the movement of water and air, provides pathways for root growth, and offers reactive surfaces for biochemical interactions and storage. Soil structure not only influences plant growth but is also shaped by it. The dynamic relationship between plant roots and soil structure is essential for healthy plant development (J. P. Lynch et al., 2021). Roots penetrate soil particles, creating pore spaces, and affecting water infiltration and nutrient uptake. Soil particles influence root penetration and water retention. Compacted soil restricts root growth and nutrient availability. Root exudates attract beneficial microbes, enhancing soil aggregation. Plant roots stabilize soil against erosion. Understanding this interaction is vital for sustainable agriculture and to promote plant health and productivity (Moran, Pierret, Nongviengkham, & Lao).

Effect of Soil Organic Matter

Soil is composed of 50% solid phase, 25% liquid phase, and 25% gaseous phase. The solid phase constitutes more than half of the soil's volume and more than 75% of its weight, and the mineral fraction is the largest proportion of the weight of the solid phase compared to the organic fraction. However, the organic fraction is a very important component due to its direct and indirect effect on other soil properties (NRCS).

The Food and Agriculture Organization of the United Nations (FAO) defines soil organic matter as all organic material found within the soil, irrespective of its source or stage of decomposition. It is divided into three groups: fully decomposed, highly stable organic matter known as humus, the biomass of soil organisms, and partially decomposed residues (FAO).

Organic matter is a mixture of different substances, such as C, O, H, N, P, and S. Thus, it helps the plant fulfill its need for nutrients, in addition to having a great ability to retain water in large quantities. The decomposition of organic matter produces amino acids and carbon dioxide, which affects the absorption of elements such as calcium, magnesium and potassium by the plant.

As previously stated, organic matter influences various soil properties. It enhances soil structure, facilitating the movement of water and air essential for plant growth. Additionally, the organic matter content directly affects soil color, with higher levels of organic matter typically resulting in darker soil. Just as soil color is important in soil classification, it is also important in raising the temperature of the soil through the absorption of heat by the dark color, thus enhancing biological processes within the soil. The enhancement of biological processes within the soil is very important because it increases soil pores, leading to an improved soil environment for many microbes and plant roots that need aeration. As mentioned earlier, an increase in soil organic matter enhances the soil's water-holding capacity. Hudson's (1994) study demonstrated that each 1% rise in soil organic matter leads to a 3.7% improvement in its water retention ability.

An example of organic matter is humus, an organic material formed when plant and animal matter decompose completely in an anaerobic environment. Humus is a blackish-brown material that contains approximately 60% carbon, 6% nitrogen, and smaller quantities of phosphorus and sulfur. Due to its slow decomposition rate, humus can persist in the soil for extended periods, often lasting hundreds of years. Like other organic matter, humus helps increase the soil's ability to hold nutrients at the sites of exchange and water. It can also function as a chelating agent, enhancing the availability of nutrients for plant uptake. In addition, Grossl and Inskeep (1991) study proved that the organic chemicals provided by humus prevent the precipitation of calcium phosphate minerals, and also keep phosphate fertilizers in their soluble form for a longer period of time.

All of these factors affect the availability of nutrients and water in the right form for the plant to be able to benefit from it (Andreux, 1996; Chaney & Swift, 1984; Konen, Burras, & Sandor, 2003; Kumar, Kaushal, Kaur, & Gulati, 2020; McCauley, Jones, & Jacobsen, 2009; Rajendra Prasad & Power, 1997).

Effect of Soil pH

Soil acidity influences the availability of essential nutrients. Most plants thrive in a slightly acidic to neutral pH range (approximately 6.0 to 7.0), which supports optimal nutrient absorption. However, when soil pH is excessively high or low, the availability of certain nutrients diminishes. For example, acidic soils can lead to toxic levels of aluminum and manganese, while alkaline soils may limit the availability of nutrients like iron, phosphorus, and manganese (Arduini, Kettner, Godbold, Onnis, & Stefani, 1998).

Soil pH significantly impacts the diversity and activity of soil microorganisms (Pietri & Brookes, 2008). These microorganisms are essential for nutrient cycling, organic matter decomposition, and disease suppression (Wei et al., 2024). Since different microbial species prefer specific pH ranges, soil pH directly influences their populations and functions. Variations in microbial activity can indirectly affect plant growth by modifying nutrient availability and soil structure.

pH affects root growth and development directly. Extreme pH levels can damage root tissues and hinder root elongation, leading to poor nutrient and water uptake. In soils with suboptimal pH levels, root penetration can be hindered, reducing the plant's capacity to access and utilize soil resources effectively (Walter, Silk, & Schurr, 2000).

Soil nutrients are vital for plant growth, with crop plants requiring macronutrients like nitrogen (N), phosphorus (P), and potassium (K) in larger quantities. These nutrients can be supplied through fertilizers tailored to meet crop-specific needs. The effectiveness of fertilizers and nutrient availability is influenced by soil pH, as it alters the types of nutrients present in the soil solution. Adjusting soil pH to optimal levels has a significant impact on essential plant nutrients, affecting their supply, solubility, microbial activity, and other related processes. For instance, higher pH levels enhance micronutrient availability compared to neutral or alkaline soils, thereby supporting plant growth (Gondal et al., 2021).

Effect of Soil Humidity

Soil humidity, also referred to as soil moisture, is one of the most crucial and impactful factors influencing plant growth. Soil moisture is the primary source of water for the plant to be absorbed by the roots until it is used in the biological processes within the plant, most importantly photosynthesis in addition to transpiration. In order for the soil to obtain the nutrients needed for growth, these elements need to be dissolved in water so that the roots can absorb them. The presence of water in the soil in appropriate amounts helps the seeds to start germination by activating some enzymes. In a balanced environment, an increase in soil water content results in a reduction of oxygen within soil pores. This lack of oxygen can cause plant roots to struggle to breathe, ultimately leading to plant death (Veihmeyer & Hendrickson, 1927).

Shortage of water affects many physiological processes. The process of cell expansion can tolerate water deficit up to -10 bar, while protein synthesis and wall synthesis can tolerate a little more. Photosynthesis and stomatal conductance can tolerate up to -20 bar. Under such conditions, the plant produces the hormone abscisic acid, which triggers the closure of stomata to reduce water stress (Allison & Jones, 2005).

Effect of Soil Salinity

Soil salinity

Soil salinity refers to the presence of soluble salts in the soil, often due to an accumulation of ions such as sodium, chloride, calcium, magnesium, and sulfate (Butcher, Wick, DeSutter, Chatterjee, & Harmon, 2016). This condition is typically quantified through electrical conductivity (EC) or total dissolved salts (TDS) in the soil solution, with measurements commonly reported in units like decisiemens per meter (dS/m) or milligrams per liter (mg/L) (El-Ghazlane et al., 2017).

Typically, soil salinity is considered high when the electrical conductivity (EC) in the root zone surpasses 4 dS/m (decisiemens per meter). At this level, the concentration of soluble salts in the soil solution becomes significant enough to potentially hinder the growth of most plants (Munns, 2005).

Table 1:
Soil Salinity classes in terms of electrical conductivity (EC) (Richards, 1954)

EC (dS/m)	Salinity class	Salinity effects on crops
< 2	Non / saline	Negligible impact on crops
2–4	Slightly saline	Growth of highly sensitive crops may be affected
4–8	Moderately saline	Yield reduction observed in a wide range of crops
8–16	Very saline	Only salt-tolerant crops achieve satisfactory yields
>16	Extremely saline	Only a few highly salt-tolerant crops yield adequately

Impacts of soil salinity on plant growth

Soil salinity has several detrimental impacts on plant growth, reduced Water Uptake and high levels of salt in the soil create an Osmotic Stress (osmotic imbalance), making it harder for plants to absorb water through their roots. and Salinity can interfere with the uptake of essential nutrients by plant roots (Razzaghi et al., 2011).

Sodium ions, in particular, can interfere with the uptake of other essential cations like potassium, calcium, and magnesium, resulting in nutrient imbalances within plants. This can negatively affect various physiological processes necessary for growth and development (J.-K. Zhu, 2002). Also, certain ions present in salt, such as sodium and chloride, can accumulate to toxic levels in plant tissues. This can disrupt cellular functions, damage cell membranes, and interfere with metabolic processes like photosynthesis and respiration. Symptoms of toxicity may include leaf burn, necrosis, and chlorosis (Chele, Tinte, Piater, Dubery, & Tugizimana, 2021).

PLANTS AFFINITY

The processes of nutrient and ion transport are vital for plant growth and development. These transport processes can be broadly divided into high-affinity and low-affinity transport mechanisms based on their efficiency and ability to transport ions or molecules under different concentrations. High-affinity transporters specialize in operating efficiently when the concentration of the substrate is very low. In contrast, low-affinity transport systems work effectively when substrate concentrations are relatively high (Dreyer & Michard, 2020).

Barley (*Hordeum vulgare L.*) has been identified as having a high affinity for potassium, a macronutrient crucial for regulating water uptake, enzyme activation, and photosynthesis in plants, as described by Epstein, Rains, and Elzam (1963). *Zea mays L.* shows a notable preference for nitrogen in the form of ammonium, which is essential for protein synthesis and overall plant growth, as demonstrated in the study conducted by Gu et al. (2013). Spinach (*Spinacia oleracea L.*) demonstrates a high affinity for calcium, a nutrient responsible for cell wall stabilization and signal transduction, according to Kreimer, Surek, Woodrow, and Latzko (1987). Rice (*Oryza sativa L.*) is known for its significant nitrogen uptake, particularly essential for chlorophyll production and grain yield, as reported by Feng et al. (2011). Pea (*Pisum sativum*) similarly exhibits a high affinity for nitrogen, a key component for legume nodulation and biological nitrogen fixation, as shown in the research by Werner and Newton (2005). Wheat (*Triticum aestivum*) displays a strong preference for phosphate, an indispensable nutrient for energy transfer, root development, and flowering, as detailed by X. Liu et al. (2013). Cucumber (*Cucumis sativus*) has been documented to efficiently absorb copper, a micronutrient vital for electron transport, lignin synthesis, and defense mechanisms, as demonstrated in the work of Migocka, Posyniak, Maciaszczyk-Dziubinska, Papierniak, and Kosieradzaka (2015). Finally, pepper (*Capsicum annuum*) has a high affinity for potassium, which plays a key role in fruit development, quality improvement, and stress resistance, as noted by Martínez-Cordero, Martínez, and Rubio (2005). These findings highlight the specific nutrient requirements and uptake mechanisms of various plant species, which are essential for optimizing growth, productivity, and agricultural management practices.

Barley (*Hordeum vulgare L.*) exhibits a low affinity for sodium, a non-essential element that can become toxic at high concentrations, as it interferes with potassium uptake and metabolic processes (Munns & Tester, 2008). Maize (*Zea mays L.*) shows a low affinity for chloride, which at excessive levels can cause ionic imbalance and osmotic stress, reducing growth and yield (White & Broadley, 2001). Spinach (*Spinacia oleracea L.*) has been observed to display a low affinity for magnesium under competitive uptake conditions, which can disrupt chlorophyll synthesis and enzyme activation (Verbruggen & Hermans, 2013). Rice (*Oryza sativa L.*) demonstrates a low affinity for iron when grown in aerobic soils, where iron availability decreases due to oxidation, leading to iron deficiency chlorosis (Mori, 1999). Pea (*Pisum sativum*) exhibits a low affinity for sulfur in sulfur-depleted soils, impairing amino acid and protein synthesis, essential for growth and nodulation (Scherer, 2001). Wheat (*Triticum aestivum*) shows a low affinity for zinc under calcareous soil conditions, where high pH reduces zinc solubility, affecting enzyme function and root development (Alloway, 2008). Cucumber (*Cucumis sativus*) has a low affinity for boron when soil mobility is limited, particularly in dry or alkaline conditions, which disrupts cell wall synthesis and reproductive development (Shorrocks, 1997). Finally, pepper (*Capsicum annuum*) demonstrates a low affinity for manganese in soils with high pH levels, where manganese availability decreases, impacting photosynthesis and enzyme activity (Marschner, 2011). These findings highlight the challenges plants face in low-affinity nutrient uptake and emphasize the need for targeted soil and nutrient management strategies to mitigate deficiencies.

CONCLUSION

The complex interaction between soil properties and plant growth emphasizes the need to understand and manage soil conditions to enhance agricultural productivity and sustain ecosystems. This review explores the critical influence of factors such as soil texture, structure, organic matter, pH, moisture, and salinity on nutrient absorption and overall plant health. Fine-textured soils like clay offer high nutrient retention but can impede root growth, whereas sandy soils, though conducive to root penetration, often require enhanced fertilization due to lower nutrient-holding capacities. Organic matter emerges as a crucial component, significantly improving soil structure, nutrient availability, and water retention. Soil pH significantly influences nutrient availability and microbial activity, with the majority of plants thriving in a slightly acidic to neutral pH range for optimal growth. Soil moisture is essential for nutrient dissolution and plant physiological processes, though excessive moisture can restrict root respiration by reducing soil aeration. Soil salinity poses a significant challenge by creating osmotic stress and potential of ion toxicity, necessitating careful management to prevent detrimental effects on plant growth.

Effective soil management practices must be tailored to address specific soil constraints, enhancing nutrient availability and promoting healthy root development. Maintaining soil health and achieving sustainable crop production require strategies like incorporating organic matter, adjusting soil pH, and managing salinity levels. Future research should prioritize innovative methods to address challenging soil conditions, enhance soil structure and fertility, and design resilient cropping systems. By integrating these approaches, we can achieve sustainable agricultural practices that support robust plant growth and long-term soil health, ultimately contributing to food security and environmental conservation.

REFERENCE

Adler, P. R., Cumming, J. R., & Arora, R. (2009). Nature of mineral nutrient uptake by plants. *Agricultural Sciences, 1*, 355-371.

Aerts, R., Boot, R., & Van der Aart, P. (1991). The relation between above-and belowground biomass allocation patterns and competitive ability. *Oecologia, 87*, 551-559.

Aiken, R., & Smucker, A. (1996). Root system regulation of whole plant growth. *Annual review of phytopathology, 34*(1), 325-346.

Alam, S. M. (1999). Nutrient uptake by plants under stress conditions. *Handbook of plant and crop stress, 2*, 285-313.

Allison, E., & Jones, C. (2005). Plant water relations. *Montana State University. Extension paper*(4481-5), 7.

Alloway, B. (2008). Zinc in Soils and Crop Nutrition. *International Zinc Association and International Fertilizer Association, 16*.

Andreux, F. (1996). Humus in world soils. In *Humic substances in terrestrial ecosystems* (pp. 45-100): Elsevier.

Arduini, I., Kettner, C., Godbold, D., Onnis, A., & Stefani, A. (1998). pH influence on root growth and nutrient uptake of Pinus pinaster seedlings. *Chemosphere, 36*(4-5), 733-738.

Arunkumar, S. (2021). Soil physical and chemical properties in relation to plant growth. *AgriCos e-Newsletter, 2*(19), 64-66.

Balandreau, J., & Knowles, R. (1978). The rhizosphere. In *Developments in Agricultural and Managed Forest Ecology* (Vol. 4, pp. 243-268): Elsevier.

Baldi, E. (2021). Soil–plant interaction: effects on plant growth and soil biodiversity. In (Vol. 11, pp. 2378): MDPI.

Bashir, O., Khan, K., Hakeem, K. R., Mir, N. A., Rather, G. H., & Mohiuddin, R. (2016). Soil microbe diversity and root exudates as important aspects of rhizosphere ecosystem. *Plant, Soil and Microbes: Volume 2: Mechanisms and Molecular Interactions*, 337-357.

Beeckman, T., & De Smet, I. (2014). Pericycle. *Current Biology, 24*(10), R378-R379.

Bell, T. L., Pate, J. S., & Dixon, K. W. (1996). Relationships between fire response, morphology, root anatomy and starch distribution in south-west Australian Epacridaceae. *Annals of Botany, 77*(4), 357-364.

Berendse, F., de Kroon, H., & Braakhekke, W. G. (2007). Acquisition, use, and loss of nutrients. In *Functional plant ecology* (pp. 259-284): CRC Press.

Bieleski, R. (1973). Phosphate pools, phosphate transport, and phosphate availability. *Annual review of plant physiology, 24*(1), 225-252.

Boyce, C. K. (2005). The evolutionary history of roots and leaves. In *Vascular transport in plants* (pp. 479-499): Elsevier.

Brundrett, M. C. (2009). Mycorrhizal associations and other means of nutrition of vascular plants: understanding the global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis. *Plant and Soil, 320*, 37-77.

Burns, R. G., & Slater, J. H. (1982). *Experimental microbial ecology*.

Butcher, K., Wick, A. F., DeSutter, T., Chatterjee, A., & Harmon, J. (2016). Soil salinity: A threat to global food security. *Agronomy Journal, 108*(6), 2189-2200.

Casper, B. B., & Jackson, R. B. (1997). Plant competition underground. *Annual review of ecology and systematics, 28*(1), 545-570.

Chaney, K., & Swift, R. (1984). The influence of organic matter on aggregate stability in some British soils. *Journal of Soil science, 35*(2), 223-230.

Chapin III, F. S., Schulze, E.-D., & Mooney, H. A. (1990). The ecology and economics of storage in plants. *Annual review of ecology and systematics*, 423-447.

Chele, K. H., Tinte, M. M., Piater, L. A., Dubery, I. A., & Tugizimana, F. (2021). Soil salinity, a serious environmental issue and plant responses: A metabolomics perspective. *Metabolites, 11*(11), 724.

Coleman, D. C., Cole, C., Hunt, H., & Klein, D. A. (1977). Trophic interactions in soils as they affect energy and nutrient dynamics. I. Introduction. *Microbial Ecology, 4*, 345-349.

Crook, M., & Ennos, A. (1996). The anchorage mechanics of deep rooted larch, Larix europea× L. japonica. *Journal of Experimental Botany, 47*(10), 1509-1517.

De Kroon, H., & Bobbink, R. (1997). Clonal plant dominance under elevated nitrogen deposition, with special reference to Brachypodium pinnatum in chalk grassland. In *The ecology and evolution of clonal plants* (pp. 359-379): Backhuys Publishers.

de Mello Prado, R., & de Mello Prado, R. (2021). Introduction to plant nutrition. *Mineral nutrition of tropical plants*, 1-38.

De Willigen, P., Nielsen, N., Claassen, N., & Castrignanò, A. (2000). Modelling water and nutrient uptake. In: Springer.

Dreyer, I., & Michard, E. (2020). High-and low-affinity transport in plants from a thermodynamic point of view. *Frontiers in Plant Science, 10*, 512268.

Duncan, W., & Ohlrogge, A. (1958). Principles of Nutrient Uptake From Fertilizer Bands II. Root Development in the Band 1. *Agronomy Journal, 50*(10), 605-608.

El-Ghazlane, O., Mathiot, C., Alzraiee, A., Singh, P. A., Longley, K., & Benes, S. (2017). Validation of the steady-state Hoffman conceptual model for determination of minimum crop leaching requirements and stakeholder outreach using csuid. *Final Report. California State University*.

Ennos, A., & Pellerin, S. (2000). Plant anchorage. In *Root methods: a handbook* (pp. 545-565): Springer.

Epstein, E., Rains, D., & Elzam, O. (1963). Resolution of dual mechanisms of potassium absorption by barley roots. *Proceedings of the National Academy of Sciences, 49*(5), 684-692.

Eshel, A., & Beeckman, T. (2013). *Plant roots: the hidden half*: CRC press.

Fageria, N. K., & Moreira, A. (2011). The role of mineral nutrition on root growth of crop plants. *Advances in agronomy, 110*, 251-331.

Fahn, A. (1982). *Plant anatomy*: Pergamon press.

FAO. Soil organic matter. Retrieved from https://www.unescwa.org/sd-glossary/soil-organic-matter

Faucon, M.-P. (2020). Plant–soil interactions as drivers of the structure and functions of plant communities. In (Vol. 12, pp. 452): MDPI.

Fazeli-Nasab, B., Piri, R., & Rahmani, A. F. (2022). Assessment of the role of rhizosphere in soil and its relationship with microorganisms and element absorption. *Plant Protection: From Chemicals to Biologicals, 225*.

Feng, H., Yan, M., Fan, X., Li, B., Shen, Q., Miller, A. J., & Xu, G. (2011). Spatial expression and regulation of rice high-affinity nitrate transporters by nitrogen and carbon status. *Journal of Experimental Botany, 62*(7), 2319-2332.

Foth, H. D. (1991). *Fundamentals of soil science*: John Wiley and Sons, Inc.

Francis, B., Aravindakumar, C., Brewer, P. B., & Simon, S. (2023). Plant nutrient stress adaptation: A prospect for fertilizer limited agriculture. *Environmental and Experimental Botany*, 105431.

Gatiboni, L. (2018). Soils and plant nutrients. *North Carolina Extension Gardener Handbook. NC State Extension, Raleigh, NC*.

Ge, N., Wei, X., Wang, X., Liu, X., Shao, M., Jia, X., . . . Zhang, Q. (2019). Soil texture determines the distribution of aggregate-associated carbon, nitrogen and phosphorous under two contrasting land use types in the Loess Plateau. *Catena, 172*, 148-157.

Gilmour, J. (1983). A guide to granadilla growing in Zimbabwe.

Gondal, A. H., Hussain, I., Ijaz, A. B., Zafar, A., Ch, B. I., Zafar, H., . . . Khan, A. A. (2021). Influence of soil pH and microbes on mineral solubility and plant nutrition: A review. *International Journal of Agriculture and Biological Sciences, 5*(1), 71-81.

Grossl, P. R., & Inskeep, W. P. (1991). Precipitation of dicalcium phosphate dihydrate in the presence of organic acids. *Soil Science Society of America Journal, 55*(3), 670-675.

Gu, R., Duan, F., An, X., Zhang, F., von Wirén, N., & Yuan, L. (2013). Characterization of AMT-mediated high-affinity ammonium uptake in roots of maize (Zea mays L.). *Plant and Cell Physiology, 54*(9), 1515-1524.

Hudson, B. D. (1994). Soil organic matter and available water capacity. *Journal of soil and water conservation, 49*(2), 189-194.

Huntley, B. J. (2023). Soil, water and nutrients. In *Ecology of Angola: Terrestrial Biomes and Ecoregions* (pp. 127-147): Springer.

Jones, C., & Jacobsen, J. (2005). Plant nutrition and soil fertility. *Nutrient management module, 2*(11), 1-11.

Kerk, N. M., & Sussex, I. M. (2001). Roots and root systems. *e LS*.

Khalil, H. A., Hossain, M. S., Rosamah, E., Azli, N., Saddon, N., Davoudpoura, Y., . . . Dungani, R. (2015). The role of soil properties and it's interaction towards quality plant fiber: A review. *Renewable and Sustainable Energy Reviews, 43*, 1006-1015.

Klepper, B. (1992). Development and growth of crop root systems. In *Limitations to plant root growth* (pp. 1-25): Springer.

Konen, M., Burras, C., & Sandor, J. (2003). Organic carbon, texture, and quantitative color measurement relationships for cultivated soils in north central Iowa. *Soil Science Society of America Journal, 67*(6), 1823-1830.

Kreimer, G., Surek, B., Woodrow, I. E., & Latzko, E. (1987). Calcium binding by spinach stromal proteins. *Planta, 171*, 259-265.

Kumar, Y., Kaushal, D., Kaur, G., & Gulati, D. (2020). Effect of soil organic matter on physical properties of soil. *Just Agriculture, 1*(2), 25-30.

Lambers, H., Raven, J. A., Shaver, G. R., & Smith, S. E. (2008). Plant nutrient-acquisition strategies change with soil age. *Trends in ecology & evolution, 23*(2), 95-103.

Lewis, D. (1984). *Occurrence and distribution of storage carbohydrates in vascular plants.* Paper presented at the Seminar series/Society for Experimental Biology.

Liu, S., Ji, X., & Zhang, X. (2022). Effects of soil properties and tree species on root–soil anchorage characteristics. *Sustainability, 14*(13), 7770.

Liu, X., Zhao, X., Zhang, L., Lu, W., Li, X., & Xiao, K. (2013). TaPht1; 4, a high-affinity phosphate transporter gene in wheat (Triticum aestivum), plays an important role in plant phosphate acquisition under phosphorus deprivation. *Functional Plant Biology, 40*(4), 329-341.

Loewus, F. A., & Tanner, W. (2012). *Plant carbohydrates I: Intracellular carbohydrates* (Vol. 13): Springer Science & Business Media.

Lynch, J. M., Brimecombe, M. J., & De Leij, F. A. (2001). Rhizosphere. *e LS*.

Lynch, J. P., Strock, C. F., Schneider, H. M., Sidhu, J. S., Ajmera, I., Galindo-Castañeda, T., . . . Hanlon, M. T. (2021). Root anatomy and soil resource capture. *Plant and Soil, 466*, 21-63.

Marschner, H. (2011). *Marschner's mineral nutrition of higher plants*: Academic press.

Martínez-Cordero, M. A., Martínez, V., & Rubio, F. (2005). High-affinity K+ uptake in pepper plants. *Journal of Experimental Botany, 56*(416), 1553-1562.

McCauley, A., Jones, C., & Jacobsen, J. (2009). Soil pH and organic matter. *Nutrient management module, 8*(2), 1-12.

Mengel, D. (1995). *Roots, growth and nutrient uptake*: Purdue University West Lafayette, IN, USA.

Migocka, M., Posyniak, E., Maciaszczyk-Dziubinska, E., Papierniak, A., & Kosieradzaka, A. (2015). Functional and biochemical characterization of cucumber genes encoding two copper ATPases CsHMA5. 1 and CsHMA5. 2. *Journal of Biological Chemistry, 290*(25), 15717-15729.

Miyanishi, K., & Kellman, M. (1986). The role of root nutrient reserves in regrowth of two savanna shrubs. *Canadian Journal of Botany, 64*(6), 1244-1248.

Moran, C. J., Pierret, A., Nongviengkham, B., & Lao, P. Plants roots and soil structure.

Mori, S. (1999). Iron acquisition by plants. *Current opinion in plant biology, 2*(3), 250-253.

Munns, R. (2005). Genes and salt tolerance: bringing them together. *New Phytologist, 167*(3), 645-663.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol., 59*(1), 651-681.

NRCCA. (2010). Basic Concepts of Soil Fertility. Retrieved from https://nrcca.cals.cornell.edu/nutrient/CA1/

NRCS. Soil. Retrieved from https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soil

Pattnaik, S., Mohapatra, B., & Gupta, A. (2021). Plant growth-promoting microbe mediated uptake of essential nutrients (Fe, P, K) for crop stress management: Microbe–soil–plant continuum. *Frontiers in Agronomy, 3*, 689972.

Pietri, J. A., & Brookes, P. (2008). Relationships between soil pH and microbial properties in a UK arable soil. *Soil Biology and Biochemistry, 40*(7), 1856-1861.

Pugnaire, F., & Valladares, F. (2007). *Functional plant ecology*: CRC press.

Rajendra Prasad, R. P., & Power, J. (1997). Soil fertility management for sustainable agriculture.

Rasmussen, A., & Schmidt, S. (2022). 4.1-Nutrient requirements and root architecture.

Razzaghi, F., Ahmadi, S. H., Adolf, V. I., Jensen, C. R., Jacobsen, S. E., & Andersen, M. N. (2011). Water relations and transpiration of quinoa (Chenopodium quinoa Willd.) under salinity and soil drying. *Journal of agronomy and crop science, 197*(5), 348-360.

Richards, L. A. (1954). *Diagnosis and improvement of saline and alkali soils*: US Government Printing Office.

Rost, T., Barbour, M., Stocking, C., & Murphy, T. (1998). The shoot system I: The stem. *Plant Biology, 85*, 104.

Roy, R. N., Finck, A., Blair, G., & Tandon, H. (2006). Plant nutrition for food security. *A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin, 16*(368), 201-214.

Ryel, R. J. (2004). Hydraulic redistribution. *Progress in botany: genetics physiology systematics ecology*, 413-435.

Scherer, H. W. (2001). Sulphur in crop production. *European Journal of agronomy, 14*(2), 81-111.

Schroth, G., & Sinclair, F. L. (2003). *Trees, crops, and soil fertility: concepts and research methods*: Cabi.

Shi, C.-L., Von Wangenheim, D., Herrmann, U., Wildhagen, M., Kulik, I., Kopf, A., . . . Albert, M. (2018). The dynamics of root cap sloughing in Arabidopsis is regulated by peptide signalling. *Nature plants, 4*(8), 596-604.

Shorrocks, V. M. (1997). The occurrence and correction of boron deficiency. *Plant and Soil, 193*(1), 121-148.

Somerville, A. (1979). Root anchorage and root morphology of Pinus radiata on a range of ripping treatments. *NZJ For. Sci, 9*(3), 294-315.

Soper, K. (1959). Root anatomy of grasses and clovers: Lolium perenne L., Dactylis glomerata L., Glyceria fluitans Br., Alopecurus pratensis L., Trifolium repens L., T. pratense L., and Lotus uliginosus Schkuhr (major Sm.). *New Zealand Journal of Agricultural Research, 2*(2), 329-341.

Staňová, A., Ďurišová, E., Banásová, V., Gurinová, E., Nadubinská, M., Kenderešová, L., . . . Čiamporová, M. (2012). Root system morphology and primary root anatomy in natural non-metallicolous and metallicolous populations of three Arabidopsis species differing in heavy metal tolerance. *Biologia, 67*, 505-516.

Staswick, P. (1994). Storage proteins of vegetative plant tissues. *Annual review of plant biology, 45*(1), 303-322.

Stern, K. R., Bidlack, J. E., Jansky, S., & Uno, G. (2008). *Introductory plant biology*: McGraw-Hill Higher Education Boston, MA, USA.
Tang, C., & Rengel, Z. (2003). Role of plant cation/anion uptake ratio in soil acidification. In *Handbook of soil acidity* (pp. 71-96): CRC Press.
Tomaszewska-Sowa, M., & Figas, A. (2011). Optimization of the processes of sterilization and micropropagation of cup plant (Silphium perfoliatum L.) from apical explants of seedlings in in vitro cultures. *Acta Agrobotanica, 64*(4).
Torrey, J. G. (1976). Root hormones and plant growth. *Annual review of plant physiology, 27*(1), 435-459.
Tromp, J. (1983). Nutrient reserves in roots of fruit trees, in particular carbohydrates and nitrogen. *Plant and Soil, 71*, 401-413.
Uchida, R. (2000). Essential nutrients for plant growth: nutrient functions and deficiency symptoms. *Plant nutrient management in Hawaii's soils, 4*, 31-55.
Valladares, F., & Niinemets, Ü. (2007). The architecture of plant crowns: from design rules to light capture and performance. In *Functional plant ecology* (pp. 101-150): CRC Press.
Veihmeyer, F., & Hendrickson, A. (1927). Soil-moisture conditions in relation to plant growth. *Plant physiology, 2*(1), 71.
Verbruggen, N., & Hermans, C. (2013). Physiological and molecular responses to magnesium nutritional imbalance in plants. *Plant and Soil, 368*, 87-99.
Walker, T. S., Bais, H. P., Grotewold, E., & Vivanco, J. M. (2003). Root exudation and rhizosphere biology. *Plant physiology, 132*(1), 44-51.
Walter, A., Silk, W. K., & Schurr, U. (2000). Effect of soil pH on growth and cation deposition in the root tip of Zea mays L. *Journal of Plant Growth Regulation, 19*, 65-76.
Wasaya, A., Zhang, X., Fang, Q., & Yan, Z. (2018). Root phenotyping for drought tolerance: a review. *Agronomy, 8*(11), 241.
Wei, X., Xie, B., Wan, C., Song, R., Zhong, W., Xin, S., & Song, K. (2024). Enhancing Soil Health and Plant Growth through Microbial Fertilizers: Mechanisms, Benefits, and Sustainable Agricultural Practices. *Agronomy, 14*(3), 609.
Werner, D., & Newton, W. E. (2005). *Nitrogen fixation in agriculture, forestry, ecology, and the environment* (Vol. 4): Springer Science & Business Media.
White, P. J., & Broadley, M. R. (2001). Chloride in soils and its uptake and movement within the plant: a review. *Annals of Botany, 88*(6), 967-988.
Willenbrink, J. (1982). Storage of sugars in higher plants. In *Plant Carbohydrates I: Intracellular Carbohydrates* (pp. 684-699): Springer.
Yu, C., Mawodza, T., Atkinson, B. S., Atkinson, J. A., Sturrock, C. J., Whalley, R., . . . Zhou, H. (2024). The effects of soil compaction on wheat seedling root growth are specific to soil texture and soil moisture status. *Rhizosphere, 29*, 100838.
Zhang, P., Wang, Y., Sheng, D., Zhang, S., Gu, S., Yan, Y., . . . Huang, S. (2023). Optimizing root system architecture to improve root anchorage strength and nitrogen absorption capacity under high plant density in maize. *Field Crops Research, 303*, 109109.

Zhu, J.-K. (2002). Salt and drought stress signal transduction in plants. *Annual review of plant biology, 53*(1), 247-273.

Zhu, J., Leung, A. K., & Wang, Y. (2023). Simulating the anchorage behaviour of plant roots of different morphological traits. *Urban Forestry & Urban Greening, 88*, 128068.

Zierer, W., Rüscher, D., Sonnewald, U., & Sonnewald, S. (2021). Tuber and tuberous root development. *Annual review of plant biology, 72*, 551-580.

The Applıcatıon Of Artıfıcıal Neural Networks In Agrıculture

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ABSTRACT

The developments in industry today and the increase in the world population are causing a rise in the need and demand for food. Contrary to the increasing food demand, existing food resources are also diminishing due to reasons such as environmental pollution and the depletion of agricultural resources. For these reasons, some measures need to be taken. The increasing use of technology in agriculture, livestock, and environmental pollution has become important for the protection of existing resources and their more efficient use. Artificial neural networks (ANN) are one of the technological developments that can be utilized. In this study, ANN is discussed in terms of its general characteristics and the construction of its neural network (NN) structure. In the study, agricultural, livestock, and air quality research conducted using the ANN method were also examined and presented in summary form. The ANN method has yielded successful results in agricultural, livestock, and air quality studies compared to traditional methods used for various purposes. The YSA method has been determined to be a useful method for the conservation of existing resources and their more efficient use, as well as providing significant savings in time, cost, and labor for people and enterprise.

Keywords: Artificial Intelligence, Artificial Neural Networks, Agriculture, Livestock, Air Quality.

INTRODUCTION

The development of technology and the increase in the world population have caused food problems to occur in the world. Due to the insufficient amount of food in the world, the need and demand for agriculture, livestock, and similar food sources are increasing. Considering the long-term expectations, it is expected that the need for animal food will rise by 70% in the world by 2050 (McFarlane, 2019; Yaman et al, 2021). The United Nations estimates that the world population will exceed 11 billion by 2100 and that the annual meat requirement will reach approximately 460 million tons (UN, 2015; Gökırmaklı and Bayram, 2018). Due to this situation, the number of animal enterprises is increasing worldwide and will continue to rise day by day.

The increase in the number of animal enterprises, the tools and machines used in agriculture and animal husbandry, and the uncontrolled increases in other sectors, especially in industry, while providing a solution to food demand, are causing a significant amount of environmental pollution due to the pollutants and harmful gases they produce. Environmental pollution causes the destruction of agricultural lands, the appearance of diseases in animals, a decrease in their productivity, and health problems for workers. Therefore, while producing a solution to meet food demand, it is necessary to monitor any potential negative situations that may arise, develop solutions to reduce the impact of pollutants, and take the necessary precautions. One of the methods that can be used for monitoring in agriculture, livestock, and other sectors, and for producing solutions more easily, is ANN. ANN are networks that emerge from the various ways neurons combine with each other.

ANN work similarly to how humans learn through experience, by starting from the examples taught to them (Öztemel, 2003; Ersoy and Karal, 2012). ANN are used in many ways such as prediction, classification, data association, and similar applications (Küçükönder, 2011).

ANN can be used for various tasks such as adjusting the settings of tools and machines, determining their operating times, monitoring the health and productivity of animals, determining the amount of pollutants to be released into the environment and taking necessary precautions, and many other similar processes, in order to reduce environmental pollution caused by the agriculture and livestock sector and to increase the amount of yield obtained.

In this study, it is aimed to introduce the ANN method, specify its features, and discuss its use for different purposes in agriculture, livestock, and air quality studies.

ARTIFICIAL NEURAL NETWORKS (ANN)

Definition of ANN

ANN are computer programs that can learn from events that have occurred through the use of the human brain and can generate ideas about events they have never encountered before based on the information they have learned. Basically, an ANN learns the input parameters entered into the system and generalizes them with similar events to obtain output results. ANN are quite helpful in reaching conclusions and decision-making stages in cases where there is no knowledge about the subject but specific examples are available (Öztemel, 2006).

General Features and Advantages of ANN

Although the characteristics of ANN vary depending on the NN and training algorithm used, they have some general features. These features; (Öztemel, 2006)

1- ANN perform machine learning and can produce similar results by learning from previously occurred events.
2- In information processing methods, they have different techniques compared to traditional programs and can perform many different tasks simultaneously.

3- ANN can learn from previously occurred events; if no event has occurred on that subject before, ANN cannot learn about that subject.
4- ANN can produce outputs based on the examples taught to them, but the network's ability to provide successful output results is related to the examples taught to the network. By teaching the NN with correct examples, very successful results can be achieved.
5- ANN establish connections between all the examples taught on the relevant topic using their own mechanism.
6- ANN can generate information within previously untrained examples based on the examples they have been taught.
7- ANN can work with incomplete information, unlike traditional systems. If the missing information is not important, successful results are obtained from the NN; if it is important information, the network's performance decreases. In cases where the network's performance is affected, completing the missing information will enhance the network's performance.
8- ANN can make decisions regarding uncertainties in events by establishing relationships between events after learning from previously occurred events.
9- ANN are tolerant of errors and do not degrade quickly. The network gradually deteriorates step by step due to missing information or faulty cells.

Disadvantages of ANN

Although the use of ANN has many advantages, it also has some disadvantages. These disadvantages; (Vural, 2007; Karahan, 2011; Öztemel, 2006)

1- There is no definitive rule for determining the structure of a ANN, and trial and error must be used to achieve the best results. Therefore, the user's experience and skill come to the forefront when creating the structure of the network.
2- ANN only work with numerical data. To use the system, the data to be used must be converted into numerical data.
3- To be able to use ANN, hardware with specific features is required.
4- One of the biggest problems is that the NN does not provide information about how and why it produced a solution after generating a solution for the given problem. This situation can create distrust in the solution produced for the user.
5- During the training process of the ANN, training is completed when the errors fall below a certain level, but the lack of a specific duration creates uncertainty regarding the training period.

Usage Types of ANN

ANN have many different usage types. Some usage types of ANN; (Öztürk and Şahin, 2018)

Prediction: ANN work to predict the value of the output parameter based on the input parameters taught to the network.

Classification: The process performed to enable the network to work faster and more accurately by classifying the input parameters taught to the ANN.

Data Association: ANN establishes connections between examples using the information it has learned and fills in missing data.

Data Interpretation: By examining the input parameters trained by the ANN, it can make interpretations about a different example based on these parameters.

Data Filtering: ANN filters the data it has obtained from the examples it has learned, selecting the most useful data.

Usage Areas of ANN

With the increasing use of ANN day by day, their areas of application are also expanding. In our world, ANN are utilized in almost all sectors imaginable to make forward-looking predictions, interpret the current situation, and classify under specific conditions. One of the most important stages of the healthcare sector, the diagnosis of diseases in patients, the implementation of certain techniques, and the treatment stages are being used and accelerating the process. It is used in the quality control of products to be manufactured in the industry, in predicting their lifespan, and in their planning. In the military industry, the use of radar is employed in the classification of sonar signals. In daily life, it is used in many areas such as predicting weather conditions to make life easier and classifying emails. (Wu and Feng, 2018)

Structure and Basic Components of ANN

Biological Nerve Cell

The biological nervous system is a system that consists of three layers, with the brain at its center, which receives, interprets, and makes decisions based on information. These layers consist of sensory neurons that send the obtained information to the brain through electrical signals, motor neurons that convert the electrical signals produced by the brain into appropriate responses, and the central nervous system that feeds forward and backward between sensory and motor neurons to produce the appropriate responses. The functioning of the biological nervous system is illustrated in Figure 1 (Fırat and Güngör, 2004).

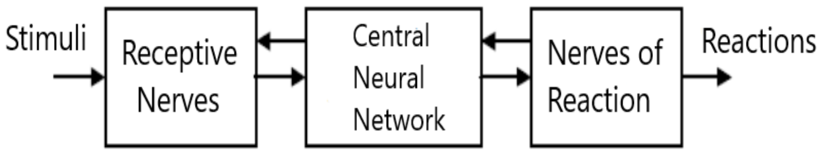

Figure 1: Representation of the Biological Nervous System (Fırat and Güngör, 2004)

The structure that performs the most vital functions of a nervous system is nerve cells. Nerve cells consist of four basic components: input (dendrite), output (axon), body, and connections (synapses). (Anderson and McNeill, 1992)

Synapses: They facilitate communication between cells because they are structures that connect neighboring nerve cells.

Dendrites: The structures that receive information from synapses, facilitating communication between cells, are called dendrites.

Axon: When the stimulus threshold of the cell body is exceeded, the cell is stimulated, and therefore, signals are sent to other cells through the axons. Axons and dendrites are similar to each other in terms of their functions, but axons are longer and more organized in structure compared to dendrites. Figure 2 shows an example of a biological nerve cell.

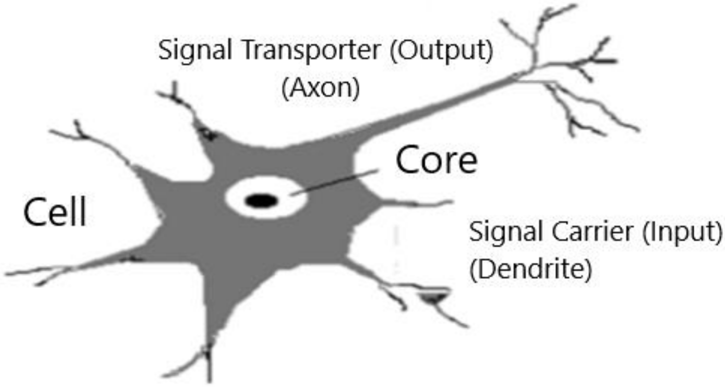

Figure 2: Biological Nerve Cell (Şen, 2004)

Artificial Neural Cell

ANN also have a similar structure to biological NN. The first artificial neuron (AN) model was created by McCulloch and Pitts (MCP) in 1943. The first AN developed is shown in Figure 3.

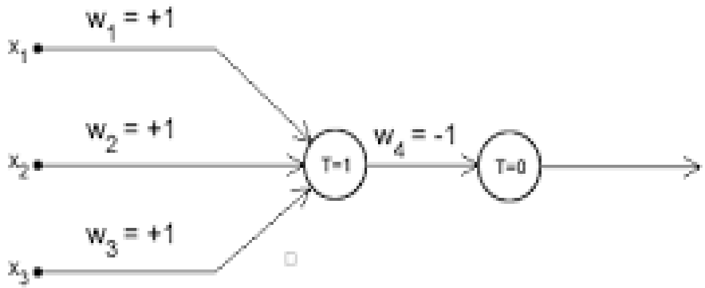

Figure 3: MCP Neuron Model

In MCP neuron model, the round shapes in the model represent the body part of a biological neuron. In the model, the dendrites that transmit signals in the biological nerve cell are represented by arrows. The model operates on the same principle as a real biological nerve cell, and not every signal received by the model is transmitted. When the total signal amount reaching the body exceeds a certain alert threshold, the signal is sent. With the development of the McCulloch-Pitts Neuron model and the connection of these neurons to form a network, ANN were created (Eğrioğlu et al. 2020).

In ANN, neurons consist of 5 basic components. These components; (Öztemel, 2006)

Inputs: The information provided to the AN from external sources or through samples from other nerve cells is referred to as inputs.
Weights: The effect of the information entered into an AN on that neuron is called weight. The large or small values that the weights take do not indicate their importance to the cell; they only show the effect of the input on the cell.
Total Function: The function that calculates the net input given to the cell is referred to as the total function. There are different functions available to perform this operation.
Activation Function: The activation function is defined as the process by which a cell produces an output value in response to a given net input. There

are also different types of functions in the activation function, but to achieve the best result, different functions need to be tried and tested.
Output: It is expressed as the output value obtained from the cell. The elements found in biological nervous system and ANN, that perform same function are shown side by side in Table 1.

Table 1: Similarities between the biological nervous system and ANN (Baş, 2006; Küçükönder, 2011)

Nervous System	**Neural Computing System**
Neuron (Nerve)	Process element
Dendirit	Total function
Cell body	Activation Function
Axons	Element output
Synapses	Weights

Structure of ANN

ANN are formed by the arrangement of artificial nerve cells in a structured manner. These cells come together in three layers and in parallel to each other to form ANN. A typical ANN model is as shown in Figure 4. These layers; (Kukreja et al. 2016).

Input layer: It is the part where the information given to the system is transmitted to the hidden layer.

Hidden layer: It is the section where data is processed. After the data is processed, it is sent to the output layer.

Output layer: The section where the output values corresponding to the initially entered information into the system are attain after the data processed in the hidden layer reaches the output layer.

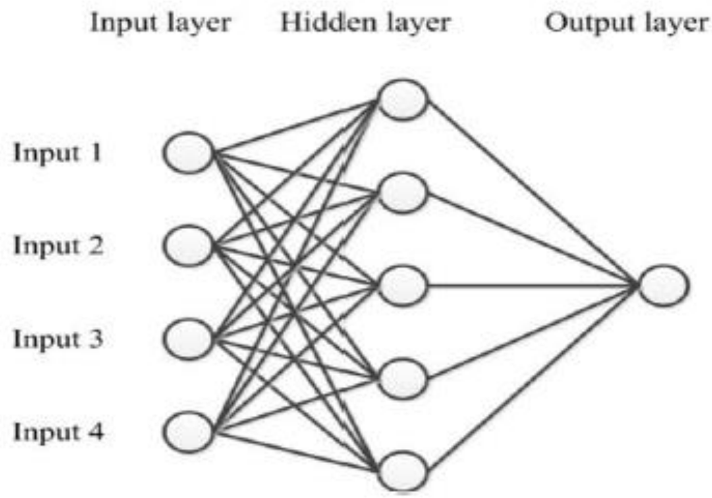

Figure 4: A typical ANN model (Dehkordi 2012; Öztürk, 2015)

Classification of ANN

ANN can generally be classified in two different ways based on their learning algorithms and structures.

Classification of ANN by Structure

ANN are divided into two groups based on their structures: feedforward and feedback NN (Ataseven, 2013).

Feedforward Networks

In feedforward ANN, inputs progress in one direction. In a NN, nerve cells are only connected to the next layer, and there is no relationship between the data in the same layer, and the system operates in a feedforward manner. The architecture of the feedforward NN is given in Figure 5 (Barutçu, 2013; Akın, 2017).

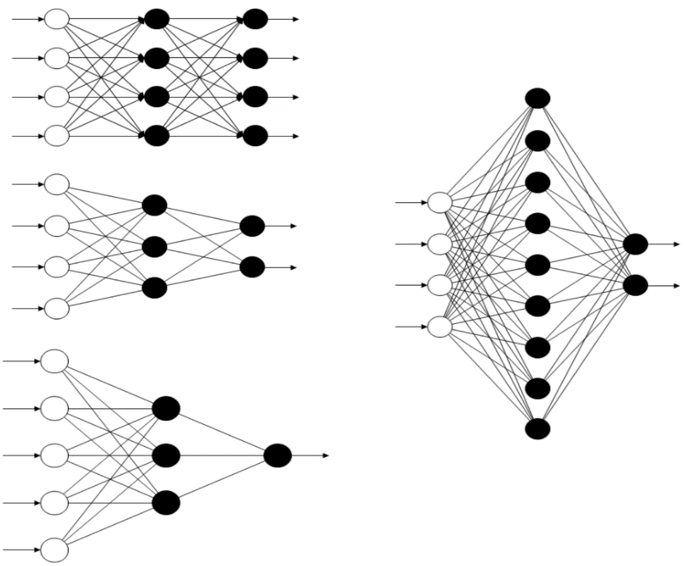

Figure 5: Feedforward NN architectures (Barutçu 2013; Akın 2017)

Feedback Networks

In feedback networks, the output values of the neurons in the layers depend on the current input values and weight values, but at the same time, unlike feedforward networks, they are also influenced by the output values of other layers and neurons. These types of networks are primarily used for making predictions. The architecture of the feedback NN is given in Figure 6 (Altınkum, 2013).

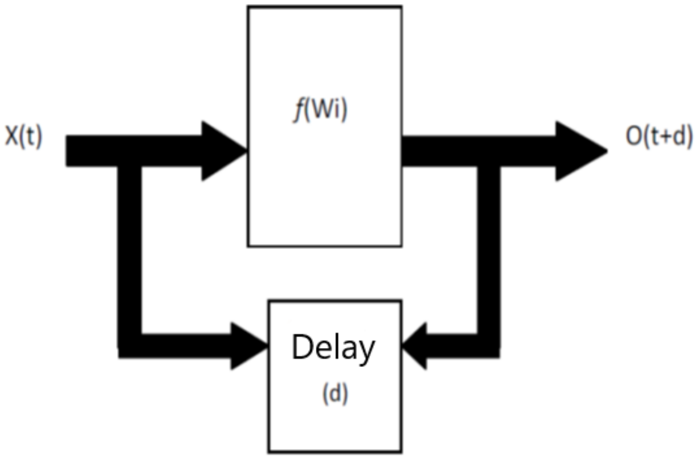

Figure 6: Feedback NN architectures (Altınkum, 2013)

Classification of ANN According to Learning Algorithms

Learning is one of the most important functions of ANN. With the occurrence of learning, the weights change in order to minimize the error amount. In ANN, three different learning algorithms can be mentioned: supervised, unsupervised, and supportive learning. (Altınkum, 2013).

Supervised Learning

In this learning algorithm, NN input and the corresponding output values for each input value are trained together. During training, the network continues training until the error amount falls below the previously determined error amount. Training is terminated and weights are obtained when the actual error amount falls below the desired error amount. Thus, it can demonstrate successful output performance in examples similar to those used for network training. The schematic of supervised learning is shown in Figure 7.

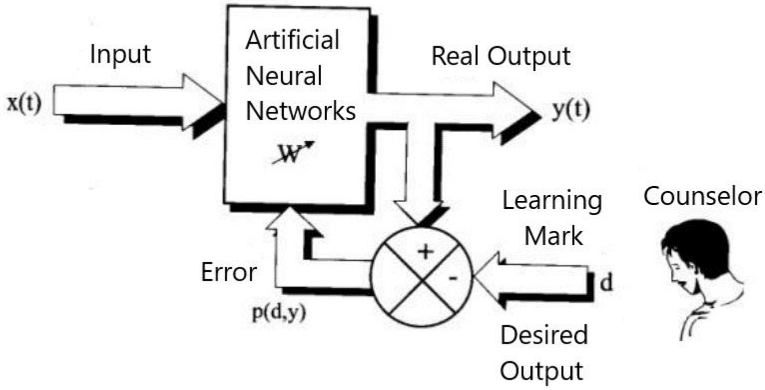

Figure 7: Supervised Learning (Sağıroğlu et al. 2004; Ataseven, 2013)

Unsupervised Learning

In unsupervised learning, only input values are given to the NN for training. Output values are not provided to the network, therefore there is no supervisor in the NN. ANN, determines the connection weights by classifying inputs that exhibit similar characteristics, creating relationships between the given inputs on its own. Unsupervised learning is mostly used for classification purposes (Baş, 2006). Figure 8 shows the schematic of unsupervised learning.

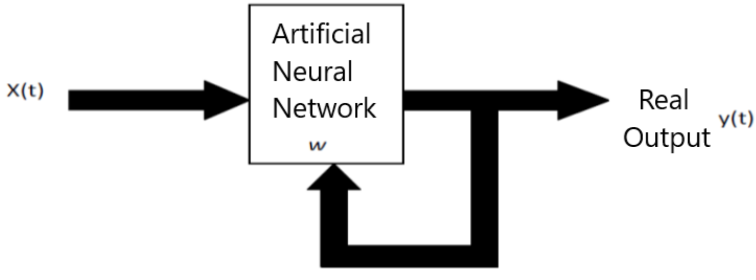

Figure 8: Unsupervised Learning (Altınkum, 2013)

Supportive Learning

In supervised learning, as in supportive learning, input and output values must be provided to the NN; however, unlike supervised learning, in supportive learning, the output values given to the network are not directly shown to the NN. The accuracy or inaccuracy of the output value obtained by NN is told to network. Thus, output value given to the network is used solely as a criterion to test the accuracy of the obtained output value, and based on this, the aim is to determine the network's connection weights in the best possible way (Özgün, 2011). The principle of supportive learning is provided in Figure 9.

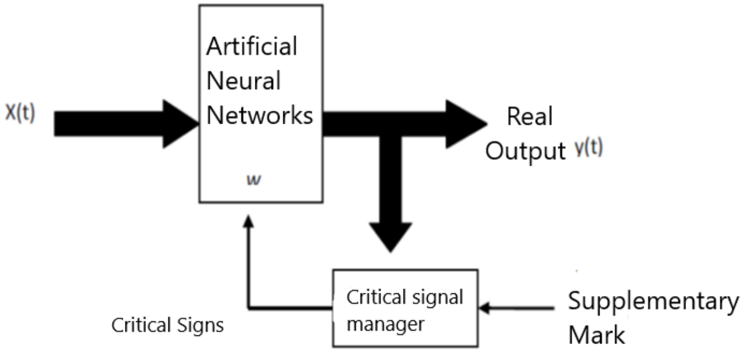

Figure 9: Supportive Learning (Altınkum, 2013)

Classification of ANN by Application

ANN are divided into two groups based on their learning types: online and offline learning (Özgün, 2011).

Online Learning

ANN that perform online learning can also carry out their other functions while learning.

Ofline Learning

Offline learning, unlike online learning, cannot create learning and other functions together. In offline learning, learning is carried out and completed through examples. Training cannot take place while the system is being used in real life.

Learning Rules in ANN

In ANN, the connection weights of the neurons are initially set randomly before learning occurs, but the connection weights are accurately adjusted by comparing the outputs of the NN with the actual output values through input and output examples provided to the system. This process is called learning. In ANN, there are some learning rules to minimize errors and achieve accurate results. The four most common learning rules are the Delta rule, Hopfield rule, Hebb rule, and Kohonen rule (Bekin, 2015; Dündar Oğuz, 2019).

Delta Rule

The Delta rule is a developed version of the Hebb rule. This rule works on the principle of constantly changing the connection weights of neurons until they reach the most suitable point in order to minimize the amount of error. The main purpose of the delta rule is to minimize the square of the error amount. Therefore, it can also be referred to as minimizing the mean of the squared errors (Küçükönder, 2011; Kayman A
kbaba, 2019).

Hopfield Rule

The Hopfield rule is largely similar to the Hebb rule, but there are a few differences between them. In the Hopfield rule, the connection weights increase or decrease by the learning coefficient depending on whether the connected neurons are active or inactive in both inputs and targeted outputs. The learning coefficient is a user-specified coefficient that can take values between 0 and 1 (Baş, 2006).

Hebb Rule

It is a learning rule developed by Donald Hebb in 1949 based on biological learning. According to this rule, if nerve cells that exchange inputs with each other interact simultaneously, their connection values increase, while if they interact at different times, their connection values decrease (Gupta, 2013).

Kohonen Rule

In the Kohonen rule, processing elements compete with each other adjust their connection weights. As a result of the competition won by the processing element with the best output data, the connection weights of other neurons can also be updated according to the connection weights of this neuron (Akbaba 2019).

Design of ANN

Selection of NN Type

There are many points to be considered when designing a network in ANN. First of all, it is necessary to act according to the type of problem to be solved when designing the network. ANN, have different types of networks and these types of networks are used for different purposes. The user needs to choose the right type of NN to successfully solve the problem they have. ANN, can be analyzed in 3 different groups as prediction, classification and data association according to their purposes. Table 2. shows which NN are used in these groups (Küçükönder, 2011).

Table 2: Types of NN and Purposes of Use (Küçükönder, 2011).

Purpose of the Network	**NN Type**	**Network Function**
Prediction	Multilayer network	The network predicts output based on inputs.
Classification	LVQ ART Probabilistic NN Counterpropagation	Classification of inputs to the network
Data Association	Hopfield Boltzmann machine	Identifying missing or incorrect inputs to the network

Selection of Learning Algorithm

In order to create a successful NN structure, the learning algorithm to be used must be chosen correctly. It is important to use learning algorithms together with neural networks with successful results. Otherwise, the performance of the neural network will decrease considerably (Altınkum, 2013).

Determination of the Number of Hidden Layers

When constructing the structure of the NN, it is necessary to determine the number of hidden layers after specifying the type of network and the learning algorithm. Number of layers may vary depending on the problem to be solved or the structure of the NN. Therefore, utilizing trial and error method is best choice (Akbaba, 2019).

Selection of Activation Function

Sigmoid and hyperbolic tangent functions are the most preferred activation functions in ANN. In ANN to be used, the output ranges are between 0 and 1 for the sigmoid function, while they vary between -1 and 1 for the hyperbolic tangent function. (Küçükönder, 2011).

Determination of the Number of Neurons

In ANN, it is necessary to resort to the trial and error method to find the number of neurons that will show the best performance. However, there is a point that needs to be considered here. Choosing too many neurons can cause the network to memorize the input data, leading to memorized results. On the other hand, having too few neurons can result in unsuccessful training and a decrease in the network's performance.

THE USE OF ANN IN AGRICULTURE, LIVESTOCK, AND AIR QUALITY STUDIES

Studies on the Use of ANN in Agriculture

In the study conducted in Iran, the greenhouse gas emissions released into the environment and the amount of energy come out during potato harvesting were estimated using ANN. For the study, 260 farms from which data were collected using the survey method were randomly selected, and the obtained data were also used for prediction with ten different input parameters. In the study, successful results were presented for predicting the potato yield energy and greenhouse gas emissions in the region under investigation (Khoshnevisan et al. 2014).

Mohamed (2019) used ANN models to predict global solar radiation in three different town in Egypt. In the study, six different climate data measured between 2002 and 2016 were used as input parameters, and the ANN was trained with two different algorithms. The obtained results have shown that the ANN method produces results with acceptable accuracy and could be a good alternative to traditional forecasting models.

Kononenko et al. (2020) utilized ANN in their study to estimate the amount of carbon dioxide emissions from agriculture in Russia. In the study, observations conducted in Russia between 1992 and 1997 were considered, using ten different input parameters, and the Adadelta algorithm was utilized as the training method. When comparing the predicted and actual values, the network created predictions that almost overlapped with the actual predictions, proving the model's feasibility.

Çelik and Köleoğlu (2022), in their study conducted in Turkey, utilized ANN and Trend analysis to determine the quantity of the lucerne plant and aimed to achieve the best result by comparing the obtained results with different error metrics. In the study, the production amount of the alfalfa plant for past years and future projections has been estimated. They reached that the ANN method produced more successful predictions compared to trend analysis and that the use of the ANN method in the field of agriculture could yield good results.

Studies on the Use of ANN in Livestock Farming

Takma et al. (2012) aimed to predict the milk yield of Holstein cows and compare the obtained results using ANN and linear regression methods in their study. In the study, three different input parameters were used in the ANN and the milk yields of the cows were predicted. It has been concluded that the predictions made using the ANN method yield results with higher accuracy compared to linear regression analysis, and that the ANN method can be successfully used in predicting milk yield.

Alias et al. (2018) utilized ANN to predict diseases affecting farm animals in Malaysia. They utilized SPSS and MATLAB software in their studies, and although the predictions made with MATLAB yielded good results, they fell short compared to the predictions made with SPSS.

Norouzian et al. (2021) compared the results of predicting movement scores for 123 dairy cows using ANN and multiple regression analysis at a dairy farm in the city of Varamin, Iran. In predicting the movement score, ANN produced more accurate results with lower errors compared to multiple regression analysis.

Yıldız and Özgüven (2022) conducted a study in a dairy cattle barn, where they predicted estrus in animals using ANN based on animal mobility and climate parameters. With their predictions made using ANN, they have achieved a successful performance with over 99% accuracy.

The Use of ANN in Air Quality Studies

Antanasijević et al. (2013) conducted PM_{10} emission predictions for the period from 1999 to 2006 for the European Union as a whole, excluding Malta, using a generalized NN in ANN. The ANN model has shown that PM_{10} emissions can be successfully and accurately predicted for up to two years. In the study, they also made predictions using traditional methods, but the ANN has much better prediction performance compared to other models.

Antanasijević et al. (2013) conducted greenhouse gas emission forecasting using ANN with twelve different input parameters for 28 European countries between 2004 and 2010. They have utilized the general regression NN and linear regression model for prediction as well. While the linear regression model made predictions with a 15% relative error, the regression NN demonstrated a much better prediction performance with a 4% relative error and produced successful results.

Stamenković et al. (2015) predicted the amount of NH_3 emissions in the Europe and USA utilizing a multilayer perceptron architecture in ANN, with four different input parameters obtained between 2000 and 2008 in their study.

At the same time, they have made predictions using a multilayer perceptron model created by applying principal component analysis to the same inputs to reduce the correlation between the inputs, and a principal component regression model, and compared the results for the three different predictions. The study has shown that the multilayer perceptron model created by applying principal component analysis has shown a more successful prediction performance compared to other multilayer perceptron models and it was concluded that ANN could be used to predict NH_3 emissions at the national level.

Akbulut and Özcan (2020) conducted a study on the prediction of PM_{10} levels in 31 provinces of Turkey using ANN and regression analysis with five different variables they identified as input parameters, examining the impact of air pollution between 2012 and 2019, and compared the results. It was concluded that ANN provided better predictions compared to regression analysis and had a lower error rate.

Özhan (2020) conducted a study using the last 55 years of greenhouse gas emission values for Turkey, predicting the amount of CO_2 emissions with ANN and Holt's linear model. In the study, ANN have a more accurate and lower error prediction performance contrast to Holt's linear model.

CONCLUSION

In this study, the ANN method is briefly described, including its features, advantages and disadvantages, and the basic components and NN structure of the ANN method. In addition to this, a literature search on the use of ANN method in agriculture, animal husbandry, and air quality has been conducted, and the studies have been presented in summary form.

The use of the ANN method for different purposes in studies on agriculture, livestock, and air quality is in question. With the advancements in technology, the use of the ANN method is steadily increasing. ANN is used in these studies primarily for prediction, as well as for classification and data association.

In livestock enterprises, the prediction and classification of animals' diseases, productivity, estrus, and mobility, the monitoring of air pollutants and greenhouse gas emissions in agriculture and other sectors, the selection of tools and machines used in agriculture and the determination of their usage duration, and the tracking of the yield amount of the produced products are widely carried out using ANN. With the increasing use of ANN, it has become an alternative method to the existing traditional methods used in similar studies.

ANN provide savings in time, cost, and labor compared to the existing traditional methods used in similar studies. The system can still function despite showing variable performance depending on the importance of missing data, unlike traditional methods. In recent years, the biggest factor in the preference for the ANN method over existing traditional methods is due to the performance of studies conducted using ANN, which have yielded more successful results compared to those conducted using traditional methods.

Due to the successful results of the ANN method in agriculture, livestock, and air quality studies, and its high advantages compared to other traditional methods, it is expected that the use of this method in the mentioned fields of agriculture and air quality will continue to increase day by day.

REFERENCES

Akbulut, İ. & Özcan, B. (2020). Hava kirliliği tahmini: Yapay sinir ağları ve regresyon yöntemleriyle bir karşılaştırma. Kocaeli Üniversitesi Fen Bilimleri Dergisi, 3(1), 12-22.

Akın, B. (2017). *Yapay sinir ağlarıyla Konya bölgesinde kullanıcı doğal gaz tüketim öngörüsü*. Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi Enerji Enstitüsü. Enerji Bilim ve Teknoloji Anabilim Dalı, İstanbul.

Alias, N., Farid, F.N.M., Al-Rahmi, W. M., Yahaya, N. & Al-Maatouk, Q. (2018). A modeling of animal diseases through using artificial neural network. International Journal of Engineering & Technology, *7(4), 3255-3262.*

Altınkum, N. (2013). *Meteorolojik Parametrelerin Atmosferik Uçucu Organik Bileşikleri Üzerine Etkisinin Yapay Sinir Ağları ile Modellenmesi*. Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, Çevre Mühendisliği Anabilim Dalı, İstanbul.

Antanasijević, D., Ristić, M., Perić-Grujić, A. A. & Pocajt, V. (2013). Greenhouse gas emissions modeling using artificial neural networks approach. 6th Symposium Chemistry and Environmental Protection with international participation. 21-24. May 2013. Vršac, Srbija.

Antanasijević, D. Z., Pocajt, V. V., Povrenović, D. S., Ristić, M. D. & Perić-Grujić, A. A. (2013). PM10 emission forecasting using artificial neural networks and genetic algorithm ınput variable optimization. Science of the Total Environment, (443), 511–519.

Ataseven, B. (2013). Yapay sinir ağları ile öngörü modellemesi. Öneri, 10(39), 101-115.

Barutçu, B., (2013). *Signal Processing and Analysis in Renewable Energy Systems,Prediction Problem*. Ders Notları, İstanbul Teknik Üniversitesi Enerji Enstitüsü.

Baş, N. (2006). *Yapay sinir ağları yaklaşımı ve bir uygulama Yüksek Lisans Tezi.* Mimar Sinan Güzel Sanatlar Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.

Bekin, A. (2015). *Türkiye'de bazı temel gıda fiyatları için yapay sinir ağları ve zaman serisi tahmin modellemelerinin karşılaştırmalı analizi*. Yüksek Lisans Tezi, Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü İşletme Ana Bilim Dalı, Denizli.

Çelik, Ş. & Köleoğlu, N. (2022). Trend analizi ve yapay sinir ağları: Tarımda bir uygulaması. Journal of Awareness. 7(1): 39-46, DOI: 10.26809/joa.7.1.03.

Dehkordi M.B. (2012). Compressive sensing based compressed neural network for sound source localization. American journal of ıntelligent systems, 2(4), 35-39.
Dündar Oğuz, Z. (2019). *Türkiye'de tasarruf açığının yapay sinir ağları modeli ile analizi*. Yüksek Lisans Tezi. Van Yüzüncü Yıl Üniversitesi Sosyal Bilimler Enstitüsü İktisat Abd İktisat Bilim Dalı. Van.
Eğrioğlu, E., Yolcu, U. & Baş, E. (2020). *Yapay sinir ağları öngörü ve tahmin uygulamaları*. Nobel Akademik Yayıncılık.
Ersoy, E., Karal, Ö. (2012). Yapay Sinir Ağları ve İnsan Beyni. Journal of the Human and Social Science Researches, 1(2).
Feng, J. & Wu. Y. 2018. Development and Applıcation of Artificial neural network. Wireless Pers Commun. 102, 1645–1656.
Fırat, M. & Güngör, M. (2004). Askı madde konsantrasyonu ve miktarının yapay sinir ağları ile belirlenmesi. İMO Teknik Dergi, 15(73), 3267-3282.
Gökırmaklı, Ç., Bayram, M. (2018). Gıda için Gelecek Öngörüleri: Yıl 2050. Akademik Gıda Dergisi. Derleme Makale. 16(3): 351-360. DOI: 10.24323/akademik-gida.475396.
Gupta, N. 2013. Artificial neural network. Network and Complex Systems. 3(1), 24-28.
Karahan, M. (2011). *İstatistiksel tahmin yöntemleri: Yapay nöron ağları metodu ile ürün talep tahmini uygulaması. Doktora Tezi*, Selçuk Üniversitesi Sosyal Bilimler Enstitüsü, Konya.
Kayman Akbaba, H. (2019). *Beyaz akaryakıt satış miktarının yapay sinir ağları ile modellenmesi*. Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstatistik Anabilim Dalı. İstanbul
Khoshnevisan, B., Rafiee, S., Omid, M., Mousazadeh, H. & Rajaeifar, M. A. (2014). Application of artificial neural networks for prediction of output energy and ghg emissions in potato production in Iran. Agricultural Systems. (123), 120-127.
Kononenko, K. & Demidov, D. (2020). Use of artificial neural networks to predict greenhouse gases emissions. Engineering for Rural Development. International Scientific Conference.20-22 May 2020.
Kukraja, H., Bharath, N., Siddesh, C. S. & Kuldeep, S. 2016. An indroduction to artificial neural network. International journal of advance research and innovative ideas in education, 1(5).
Küçükönder, H. (2011). *Yapay sinir ağları ve tarımda bir uygulama*. Doktora Tezi, Kahramanmaraş Sütçü İmam Üniversitesi Fen Bilimleri Enstitüsü. Zootekni Anabilim Dalı, Kahramanmaraş.
McFarlane, G. R. Salvesen, H. A. Sternberg, A. and Lllco, S. G. (2019). On-Farm Lvestock Genome Edtng Usng Cuttng Edge Reproductve Technologes. Fronters n Sustanable Food Systems, 3, s. 106.
McNeill, G. & Anderson, G. (1992). Artificial Neural Networks Technology. A dacs State-of-the-Art Report. USA.
Mohamed, Z. E. (2019). Using the artificial neural networks for prediction and validating solar radiation. Journal of the Egyptian Mathematical Society, 27(47).

Norouzian, M. A., Bayatani, H. & Alavijeh, M. V., (2021). Comparison of artificial neural networks and multiple linear regression for prediction of dairy cow locomotion score. Veterinary Research Forum, 12 (1), 33 – 37.

Özgün, A. (2011). *Yapay sinir ağları ile risk öngörüsü.* Doktora Tezi, Marmara Üniversitesi Sosyal Bilimler Enstitüsü, Gazetecilik Anabilim Dalı, İstanbul.

Özhan, E. (2020). Yapay sinir ağları ve üstel düzleştirme yöntemi ile Türkiye'deki CO2 emisyonunun zaman serisi ile tahmini. Avrupa Bilim ve Teknoloji Dergisi. (19), 282-289.

Öztemel, E. (2003). Yapay Sinir Ağları, Papatya Yayıncılık, İstanbul.

Öztemel, E. (2006). *Yapay sinir Ağları*. Papatya Yayıncılık. İstanbul.

Öztürk, Z. C. (2015). *Modelling of atmospheric SO2 Pollution ın Seydişehir town by artificial neural networks*. Yüksek Lisans, Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Çevre Mühendisliği Ana Bilim Dalı, Konya.

Öztürk, K. & Şahin, M.E. (2018). Yapay sinir ağları ve yapay zeka'ya genel bir bakış. Takvim-i Vekayi. 6(2), 25-36.

Sağıroğlu, Ş., Beşdok E. & Erler, M. (2003). *Mühendislikte yapay zeka uygulamaları I: Yapay sinir ağları*. Ufuk Kitap Kıratsiye-Yayıncılık.

Stamenković, L. J., Antanasijević, D. Z., Ristić, M, D., Perić-Grujić, A. A. & Pocajt, V. V. (2015). Modeling of ammonia emission in The USA and Eu countries using an artificial neural network approach. Environmental Science and Pollution Research, (22) ,18849–18858

Şen, Z. (2004). *Yapay sinir ağları ilkeleri*. Su Vakfı Yayınları.

Takma, Ç., Atıl, H., Aksakal, V. (2012). Çoklu Doğrusal Regresyon ve Yapay Sinir Ağı Modellerinin Laktasyon Süt Verimlerine Uyum Yeteneklerinin Karşılaştırılması. Kafkas Universitesi Veteriner Fakultesi Dergisi, 18 (6): 941-944.

UN, (2015). World population prospects: the 2015 revision, key findings and advance tables. United Nations Department of Economic and Social Affairs and Population Division, Working Paper No ESA/P/WP. 241.

Vural, B. B. (2007). *Yapay sinir ağları ile finansal tahmin*. *Yüksek Lisans Tezi*, Ankara Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı, Ankara.

Yaman, H., Sungur, O., Dulupçu, M. A. (2021). Dünyada Tarım ve Hayvancılığın Dönüşümü: Teknolojiye Dayalı Uygulamalar ve Devrimler. Tarım Ekonoms Dergsi. Derleme Makale. 27 (1).

Yıldız, A. K. &Özgüven, M. M. (2022). Determination of estrus in cattle with artificial neural networks using mobility and environmental data.Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi. 39(1), 40-45.

Design of Fruit and Vegetable Storage Structures

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ABSTRACT

Turkey is a major fruit and vegetable producer country. In fruit and vegetable production, major losses can occur until the product reaches the market after harvest. In order for the product obtained after the intensive harvest period to gain value in the market, to be consumed when needed or to be used in food businesses, it must be stored in suitable environments. A product stored in a good environment can maintain its quality characteristics. For this reason, storage structures have been established quite intensively, especially in fruit and vegetable production regions.

In this study, the purpose of storage was first stated, and information was provided on storage criteria such as respiration factor, temperature and relative humidity, taking into account product characteristics. Then, natural storage structures and cold storages, controlled atmosphere storage and hypobaric storage technique were emphasized. Simple structures and the use of fairy chimneys for storage purposes were evaluated as natural storage structures. The design features of commonly used cold storages were specified. Information was provided on controlled atmosphere and hypobaric storage systems, which are designed with the use of advanced technology today and which restrict the physiological activities of the product, extend its storage life and increase its quality.

Keywords – Storage, Natural Storage, Cold Storage, Controlled Atmosphere, Fruit

INTRODUCTION

In addition to its historical importance for Turkey, the agricultural sector still has a strategic importance with the net foreign exchange input it provides today and the huge employment it provides when related sectors such as packaging, transportation, etc. are included. Plant production is the locomotive sector of Turkish agriculture. Turkey is one of the rare countries where fruits and vegetables can be grown in good conditions and with high quality thanks to its fertile and large agricultural areas suitable for production and the ecological differences of different regions. With the advantage of its ecological conditions, temperate; subtropical and tropical products can also be grown (İTO, 2023).

According to 2022 data from the United Nations Food and Agriculture Organization (FAO); while fresh fruit production was carried out on 44.15 million hectares of land in the world in 1990, fresh fruit production was carried out on a total of 67.49 million hectares of land in 2022 (Anonymous

2024a). The FAO CSD reports a total world fruit production of 887,027,376 metric tons in 2020. (Anonymous 2024b) Vegetable and fruit farming in Turkey is done as intensive agriculture, with high operating costs but high returns per unit area.

Turkey is the fourth largest fruit-producing country in the world with an annual production of 25 million tons. (Anonymous 2024c) In Turkey, 3.37% of the approximately 24 million hectares of agricultural land is used for vegetable farming, while 13.7% is used for fruit farming (Anonymous, 2017). When we look at Turkey's fruit production composition, the berry group comes first with a production of 4.1 million tons and a share of 24.75%. Apple is the second most produced fruit after grapes with a production of 2.4 million tons and a share of 14.6% (TUIK, 2016). 5-40% of the fresh fruits produced are thrown away by rotting before reaching the consumer (Sayılı et al., 2006). In order to prevent this deterioration and preserve the quality, it is possible to preserve them for a certain period of time in cold storage conditions specific to each product (Yılmaz et al., 2010). Cold storage facilities are facilities where fruits and vegetables are stored without spoiling, preserving their freshness and appearance until the moment of use. Nutritional needs, which are the most important stage of life, require maximum utilization of food products, not wasting them, and preserving them without losing too much nutritional value. With its current status, it would not be wrong to describe the application areas of cooling systems as "unlimited" and to see them as a part of daily human life (Alkaş 2006).

The history of storing products dates back to the history of humanity. Humanity has given great importance to the preservation, protection and storage of agricultural products in order to be able to consume them in the following days, weeks and months or to evaluate them commercially. In the past, the storage of products was carried out in simply prepared containers, wells and cellars without any temperature and humidity control. Today, storage activities have entered a very rapid development process with the help of science and technology. Nowadays, long-term storage of products is carried out in modern facilities, with the help of machines, in a way that minimizes spoilage and decay in the product by controlling the temperature and humidity composition of the cooling environment. Thanks to these developments, products can be stored for longer periods today, quality loss caused by storage decreases, the commercial return of the stored product increases even more, it is possible to find fresh fruits and vegetables at affordable prices in every season, and this activity creates employment in many sectors from packaging to transportation.

The main purpose of storage is to preserve product quality, control diseases, protect the excess product of the business and ensure consumability in all seasons. In this context, storages should provide conditions that will preserve the appearance, structure, moisture content, nutritional value, taste and quality of the products and prevent the activities of microorganisms. No vegetable or fruit can be removed from storage in a better condition than when it was at its freshest. However, the amount of deterioration and the length of storage time vary depending on the type of vegetable or fruit stored (Olgun 2009).

Today, storage activities have entered a very rapid development process with the help of science and technology. Thanks to these developments, products can be stored for longer periods of time, quality loss due to storage is reduced, the commercial return of the stored product is increasing, it is possible to find fresh fruits and vegetables at affordable prices in every season, and this activity creates employment in many sectors from packaging to transportation (Sargın and Okudum, 2014).The products obtained as a result of agricultural production activities concentrated in certain months of the year are stored in cold storage and offered to the consumer within a wider range of time. In this way, the producer increases his income by finding the opportunity to offer his product to the market at more favorable prices, and the consumer can obtain the product he demands for a longer period of time and with higher quality features. On the other hand, with the storage of agricultural products; the working hours in agriculture-based industry (businesses such as canned food, tomato paste, fruit juice factories, deep-freezing facilities) will be extended during the year, and the development of the regional economy will be positively affected (Kuzucu and Sakaldaş, 2000).

PURPOSE OF PRODUCT STORAGE

No matter how well the optimum storage conditions are provided, each fruit and vegetable can only last for a certain period of time. This period varies from a few days to 5-6 months. At the end of these specific periods specific to each product, the stored product rapidly loses its quality and eventually spoils completely.

The most important factor in cold storage is the storage temperature. As a general principle, the temperature in storage is 1-2°C above the freezing point of the stored fruit or vegetable.

The principle in cold storage is to provide the necessary conditions to allow the metabolic activities of fruits and vegetables to occur at the lowest level without stopping them at all. The most important metabolic events are respiration and sweating. While a small portion of the heat released in this way is spent in the chemical reactions taking place in the cell, a large portion is spread to the surroundings and naturally heats the product.

Basic Principles of Storage

The characteristics of the stored products and the storage conditions accordingly are given below (Thompson 2016, Khan et all. 2017);

Respiration Factors Affecting Respiration Rate

For fruits and vegetables to continue to live, various reactions must occur in the cell. Energy is needed for these reactions to occur, and fruits and vegetables respire to provide this energy.

Under normal conditions, fresh fruits and vegetables respire aerobically. While oxygen and glucose are consumed in respiration, carbon dioxide, water and heat are formed. However, in the respiration of fruits and vegetables, gas is taken in and given out through the intercellular spaces, by the diffusion of gases. The oxygen taken in is spent, especially and primarily in the slow oxidation of water-soluble carbohydrates, while heat is released, CO_2 and H_2O are formed.

The respiration rate of each fruit and vegetable is different. For this reason, while some have slow respiration and a low heat release, some have fast respiration and excessive heat release. For example; The respiration rate is very high in vegetables such as peas and beans. As a result of natural aging occurring in a very short time, their shelf life is also short. On the other hand, vegetables such as onions and potatoes, which are storage organs, have low respiration rates and therefore have long shelf lives.

Ambient Temperature and Relative Humidity

The most important factor affecting respiration rate is ambient temperature. By lowering the temperature in storage rooms, the processes of respiration and transpiration are reduced. This prevents the spoilage of vegetables and fruits and ensures high quality. As ambient temperature increases to 37 ^{0}C, respiration rate increases and the heat emitted by the product increases accordingly. On the other hand, as the ambient temperature decreases, respiration rate also decreases. This phenomenon is used in cold storage of fruits and vegetables and the most important metabolic event, respiration rate, is limited and controlled by reducing the storage temperature. In cold storage, it is necessary to constantly remove this heat from the storage. As the ambient temperature decreases, respiration rate also slows down and when the product freezes, respiration stops completely.

High relative humidity is as important as low temperature in the storage of vegetables and fruits. High relative humidity reduces the transpiration process, which prevents water loss and wilting of products. Although a decrease in air temperature increases the relative humidity, the humidity in the storage environment should be checked regularly. A very high relative humidity can also lead to the proliferation of bacteria and spoilage of the product. Table 1 shows the storage temperature, relative humidity and storage times of various fruits and vegetables.

Amount of ethylene in the environment

Ethylene is a plant hormone and plays a key role in the ripening and premature aging of fruits and vegetables. Climacteric fruits and vegetables, which are able to ripen on their own, continue to emit gaseous Ethylene - a natural growth hormone - during storage. All plant cells synthesize small amounts of ethylene, but some stress factors stimulate the cell's ethylene synthesis. These factors also trigger excessive water loss, physical decomposition and pathogen attacks.

Ethylene biosynthesis and inhibition

Ethylene synthesis in ripening fruits occur auto catalytically. In other words, ethylene stimulates its own synthesis. Auto catalytically increasing ethylene synthesis and diffusion cause simultaneous and rapid ripening. Ethylene entry into plant tissue occurs in the form of diffusion from the membrane into the cell. Its distribution within the tissue is thought to occur through the regions where gases are present in the intercellular spaces or in the form of transmission from cell to cell in dissolved form.

Table 1. Storage Requirements for Common Vegetables and Fruit Life

Produce	Temperature (ºC)	Relative Humidity	Avg. Storage
Apples	0	90- 95%	4-6 months
Beets	0	95%	1-3 months
Brussels Sprouts	0	90-95%	3-5 weeks
Cabbage	0	90-95%	3-4 months
Carrots	0	90-95%	4-6 months
Cauliflower	0	90-95%	2-4 weeks
Celeriac	0	90-95%	3-4 months
Chinese Cabbage	0	90-95%	1-2 months
Dry Beans	0-10	65-70%	1 year
Garlic	0	65-70%	6-7 months
Horseradish	-1-0	90-95%	10-12 months
Kale	0	90-95%	10-14 days
Kohlrabi	0	90-95%	2-4 weeks
Leeks	0	90-95%	1-3 months
Onions	0	65-70%	5-8 months
Parsnips	0	90-95%	2-6 months
Pears	0	90-95%	1-2 months
Sweet Peppers	7-10	90-95%	8-10 days
Potatoes	3-4	90%	5-8 months
Pumpkins	10-13	70-75%	2-3 months
Rutabaga	0	90-95%	2-4 months
Salsify	0	90-95%	2-4 months
Sweet Potato	13-16	85- 90%	4-6 months
Tomatoes (green)	13-16	85-90%	2-6 weeks
Turnips	0	90-95%	4-5 months

Source: Khan et all. 2017

When fruits and vegetables are stored in cold storage, the amount of ethylene increases over time in closed storage. As ripening continues in the stored product, ripening accelerates even more as ethylene increases in the storage atmosphere and the product may deteriorate. For this reason, the formation and collection of ethylene in cold storage is undesirable. Ethylene must be removed from the cold storage from time to time or the product is stored under a certain vacuum. Products such as bananas are harvested, transported and stored in a green state. However, simultaneous ripening is performed with the help of ethylene gas before sale and presented to the market.

The amount of oxygen and carbon dioxide in the environment

The oxygen and carbon dioxide ratios in the storage atmosphere are also important factors affecting the respiratory rate. By decreasing the oxygen ratio in the storage atmosphere and increasing the carbon dioxide ratio, the respiratory rate can be slowed down. Taking advantage of this fact, the controlled atmosphere (CA) storage technique was developed. The modified atmosphere packaging (MAP) technique is also based on the same principle.

Transpiration

Another of the most important signs of the vitality of fruits and vegetables is transpiration. The loss of moisture from fresh fruits and vegetables is also called transpiration. The rate of transpiration varies with environmental conditions such as temperature, relative humidity, and air movement. Also, the rate of transpiration is different for different fruits and vegetables. Transpiration is the continuous loss of water by the product during storage. Fruits and vegetables contain an average of 75-95% water. Some of this water is lost during storage by sweating. As a result of the loss of water due to sweating, fruits and vegetables become shriveled and wrinkled, thus causing a loss of quality in appearance. As a general principle, fruits lose approximately 4-6% of water and vegetables lose 3-5% of water, causing them to wrinkle and shrivel.

METHODS APPLIED IN STORAGE

Simple and cooling-based storage structures can be designed in accordance with the basic storage principles above.

Small-scale and widely used underground storage structures have been a method used for many years. In simple storages, the system is based on the cooling of the product by taking the cold external air into the storage by natural or forced convection. In simple storages, good heat and moisture insulation is required. This type of storage is easy and cheap to build and operate. It is used successfully especially in continental climate regions where the temperature differences between day and night are large. Thermal insulation may not be applied to surfaces that remain underground. Simple pits dug underground and used in the storage of products are the simplest type of storage.

Fairy chimneys in the Cappadocia region of Türkiye are used for product storage (Figure 1). Mainly citrus products, potatoes and apples are stored in the warehouses carved into the tuff rocks. The citrus fruits that arrive in the warehouses, which number about two thousand in Nevşehir, in February can be kept until September. The importance of rock-carved natural cold storages with a capacity of 1.25 million tons for Nevşehir is increasing day by day. These places, which are generally used as potato and lemon storage, are used intensively in settlements connected to the center of Nevşehir, in the town of Ortahisar in the district of Ürgüp and in the district of Derinkuyu. Small-scale rock-carved storages, which were opened with manual labor in previous periods, have become large structures in which vehicles can move thanks to technological developments and machines. The fact that trucks and lorries can easily enter these cold storages and that these storages have a larger volume compared to other storages in the region is considered as an important advantage. Maintenance and repair operations of natural storages are less and their usage periods are longer. This situation has brought the region to the forefront in terms of storage. In natural cold storages carved into tuff rocks, which are warm in the winter and cool in the summer, thousands of tons of products are stored without using any equipment as an air conditioning system and without spending any energy. Thus, a great cost advantage is provided. In rock-carved warehouses, unlike classical warehouses, there is less loss of stored products, and due to features such as constant temperature and humidity balance, the natural structure of the stored products is preserved without deterioration. (Güngör and Uysal, 2017)

Figure 1: Nevşehir Natural Storage Environment (Source: Yılmaz and Balbozan, 2017).

Cold Storage has an important place in extending the storage life of products and preserving their natural properties without deteriorating (Figure 2). Materials with a risk of premature deterioration such as agricultural products, bakery products, aquatic products, medical and medicinal products; must be protected in Cold Storage and standards from the first stage to the last stage, i.e. from production to consumption.

Cold Storage is an area that allows the product to be preserved at low temperatures, frozen or low temperatures. The purpose of designing these storages is to ensure that the appropriate temperature and humidity balance is maintained according to the product. Thus, products can be stored economically and in healthy conditions for a long time.

Many different products can be stored with cold storage. Different food products such as fruits and vegetables, meat products, dairy products and fish can be stored. These products are affected by the temperature and humidity balance of the environment. While temperature change triggers the reproduction of microorganisms, moisture loss of the product can reduce its quality and cause weight loss. Therefore, both temperature and humidity levels should be monitored in the cold storage. Industrial cooling devices and humidification systems are used to ensure this.

Cold Storage is a special room where the air conditions are constantly monitored and isolated in a way that there is no air exchange with the outside. It is not affected by the outside climate conditions thanks to the insulated parts used. The air inside is ensured to reach all surfaces and the entire warehouse equally. Cold storage is designed according to the product to be stored.

Figure 2: Cold Storage (www.tamgucsogutma.com.tr)

Controlled atmosphere storage involves changing the air composition in the storage environment and maintaining this change. In this system, CO_2 and O_2 levels differ significantly from normal atmospheric air. This method is carried out by reducing the oxygen rate in particular. This technology helps to maintain the changed air by ensuring gas tightness in the room. In this way, the respiration rate of the products decreases, the metabolism slows down and the ripening and aging processes are delayed. As a result, the products maintain their freshness for longer than normal storage periods. (Thompson 1998)

Gas tightness is a critical factor for the success of controlled atmosphere storage. High-quality materials and advanced engineering techniques are used to ensure gas tightness. Keeping the air composition in the storage at the desired levels ensures that the products are stored in the most suitable conditions. Ventilation systems enable the air in the storage to be renewed regularly and to remain in the desired composition (Figure 3).

Reducing the oxygen rate reduces the respiration rate of the products and slows down the metabolism. This slows down the biological processes of the products and delays the spoilage and aging processes. Controlled atmosphere storage systems optimize this process and preserve the freshness and nutritional values of the products for a long time.

The storability of fruits and vegetables is strictly related to their respiration rate, which is an expression of metabolic activity. Aerobic respiration requires O_2, and results in CO_2 and heat release. More than 95% of the energy released is lost as heat. The temperature decrease, in particular if helped by modification of the atmosphere leads to a reduction in respiration rate, and therefore to an increase in storage life in fruits with climacteric respiration (Bodbodak and Moshfeghifar 2016).

Figure 3: Controlled atmosphere storage (https://sogutmadunyasi.com)

Hypobaric storage, known as the low-pressure storage technique, is a storage method that has been around the world for about 40 years. Hypobaric storage is not suitable for the storage of all products today, but is an important storage technique applied mostly for the storage of fresh fruit and vegetable products at low pressure and low oxygen after harvest. The reason for its application in fresh fruit and vegetables is that these products respire rapidly due to their high water content. This technique also has important advantages such as slowing down the respiration of the fresh product due to the low oxygen applied during storage, removing ethylene and other metabolic volatile substances, and delaying the progression of ripening and aging (An et al., 2009).

Hypobaric storage is a technique developed to effectively overcome the disadvantages of refrigerated and controlled atmosphere storage by removing heat generated in the environment, reducing oxygen levels, and expelling harmful gases that occur over time (Wang et al., 2001). One of the most important issues to consider in hypobaric storage is to ensure that the desired low pressure level is maintained continuously within the tank. The basis of the hypobaric storage technique is generally based on maintaining low pressures below 200 mmHg (26.7 kPa) (Thompson 2016). The low pressure required in the tank is provided by balancing the air inlet and outlet to the tank and by pressure regulators. The pressure in the tank can be measured easily with the help of a pressure gauge.

REFERENCES

An DS., Park E and Lee DS., (2009). Effect of hypobaric packaging on respiration and quality of strawberry and curled lettuce. Postharvest Biology and Technology, 52:78-83.

Alkaş, B., (2006). Kivi Meyvesi İçin Bilgisayar Destekli Soğuk Hava Depo Tasarımı. Yüksek Lisans Tezi. Ankara Üniversitesi Fen Bilimleri Enstitüsü, Ankara, 112s.

Anonymous (2024a). Global area of fresh fruit harvested from 1990 to 2022. https://www.statista.com/statistics/262270/global-production-of-fresh-fruit-worldwide/

Anonymous (2024b). Fruit Production by Country 2024. https://worldpopulationreview.com/country-rankings/fruit-production-by-country

Anonymous (2024c). List of Top 10 Fruit Producing Countries in the World. https://www.geeksforgeeks.org/fruit-producing-countries-in-the-world/

Bodbodak S. and M. Moshfeghifar (2016). Advances in controlled atmosphere storage of fruits and vegetables.

Falagán N and LA.Terry (2018). Recent Advances in Controlled and Modified Atmosphere of Fresh Produce. Johnson Matthey Technol. Rev., 2018, 62, (1), 107–117

Güngör Ş and A Uysal (2017). Postyapısalcı Coğrafyalarda İlişkisel Bir Mekân Olarak Nevşehir'in Kavak Beldesi'ndeki Doğal Soğuk Hava Depoları. Marmara Geographical Review /Issue: 36/pp: 218-231

İTO (2023). 2023 Yılı Yaş Meyve Ve Sebze Sektör Raporu İzmir Ticaret Odası. www.itb.org.tr

Khan FA, SA Bhat and S Narayanet (2017). Storage Methods for Fruits and Vegetables. Sher-e-Kashmir University of Agricultural Sciences and

Technology of Kashmir, Shalimar. Downloads/ StorageMethods forfruitsandVegetables Final %20(1).pdf

Kuzucu, F. C., Sakaldaş, M., (2000). Çanakkale İlindeki Meyve ve Sebze Soğuk Hava Depolarının Genel Durumu. Soğuk Zincir ve Lojistik Dergisi. 1(3): 17-21.

Sargın, S., Okudum, R., (2014). Isparta ilinde soğuk hava depolarının kuruluşu, gelişimi ve gelişime etki eden faktörler, SDÜ. Fen Edebiyat Fakültesi Sosyal Bilimler Dergisi. 31: 111–132.

Sayılı, M., Barut, A., Tokatlı, M., Yıldız, M., (2006). Tokat ilinde meyve ve sebze depoculuğunun mevcut durumu, sorunları ve çözüm önerileri. Gıda Teknolojileri Elektronik Dergisi. 3: 27–36.

Olgun, M., (2009). Tarımsal Yapılar, Ankara Üniversitesi Ziraat Fakültesi Tarımsal Yapılar ve Sulama Bölümü Yayın No:1577, Ders Kitabı No:529, Ankara, 445s

Thompson, A.K. (1998). Controlled Atmosphere Storage of Fruit and Vegetables, CAB International, UK.

Thompson A.K., (2016). Fruit and Vegetable Storage Hypobaric, Hyperbaric and Controlled Atmosphere. Springer International Publishing AG Switzerland

TÜİK, (2017). Tarımsal Üretim İstatistikleri. www.tuik.gov.tr

Wang L., Zhang P and Wang SJ., (2001). Advances in research on theory and technology for hypobaric storage of fruit and vegetable. Storage and Process, 5:3-6.

Yılmaz, D., Uyasal, Ö., Akman, H.E., (2010). Isparta ilindeki bazı soğuk hava depolama ve paketleme işletmelerinin mekanizasyon düzeyinin belirlenmesi. 26. Tarımsal Mekanizasyon Ulusal Kongresi. Hatay. 153–159.

Yılmaz A.M. and Z Balbozan, (2017). Asırlık Buzdolapları. https:// medium. com/@zeynepbalbozan/do%C4%9Fal-so%C4%9Fuk-hava-depolari-b0a48912060e

Emerging New Discipline: Biosystems Engineering

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ABSTRACT

Today's educational systems are needed to continuously improved according to needs for society, related sectors and the necessities of the time. During the last four decades decrease in student enrollment, rapid development in technologies enforced the transition from classical agricultural engineering education to bio based engineering programs such as biosystems engineering, agricultural and biological systems engineering etc., firstly the US and followingly other countries. The number of biosystems engineering programs either undergraduate or M.S. and PhD are continuously increased worldwide. In addition, the curriculum of these programs are continuously improved according to the needs of the age.

Keywords – Agriculture, Education, Biosystems, Engineering, Biological Systems

HISTORICAL BACKGROUND

Biosystems engineering is emerging new discipline related to the analysis, design and control of biologically based systems for the sustainable production and processing of food and biological materials and the efficient use of natural and renewable resources to improve human health in an environmentally friendly manner.

The agricultural engineering profession was firmly established in the early Twentieth Century with the founding of the American Society of Agricultural Engineers (ASAE) in 1907. Most of the founding ASAE members were composed of individuals with an interest in agriculture who were trained in Civil or Mechanical Engineering (Tao et al., 2006). Because of several problems such as economic difficulties, declining student enrollment, and society's needs for renewable energy sources, industrial materials, and environmental stewardship, many engineering departments in the United States have incorporated various components of biological engineering into traditional agricultural engineering programs. In 1966, the Agricultural Engineering department at North Carolina State University changed its name to "Biological and Agricultural Engineering." Followingly, similar departments at Rutgers and Mississippi State University also changed their names (Stewart, 1979).

In 1993, ASAE changed its name from the American Society of Agricultural Engineers to ASABE: The Society for the Engineering of

Agriculture, Food, and Biological Systems. With these developments, many academic departments changed their names to biological engineering or something similar. After this evolutionary efforts, the number of “bio” type programs surpassed the number of agricultural engineering programs for the first time in 1997, and their share in agricultural engineering curricula increased from 4% in 1987 to 85% in 2002 (Young, 2006).

While the ASABE defines biological engineering as a *“…applies engineering to problems and opportunities presented by living things and the natural environment”,* the Institute of Biological Engineering had been reached a consensus to define biological engineering as *“the biology-based discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem level”* (Scott, 2006).

After this transition in the United States, there has been a rapid change worldwide, and the number of programs giving biosystems engineering education at undergraduate and graduate level has increased rapidly (Table 1). The need of contemporary societies for a cleaner environment, protection of world resources, healthier food, and sustainable production contributed to restructure the classical Agricultural Engineering education program in Europe as to Biosystems Engineering. However, contrarily the United States, which has undergone tremendous change in recent years, there are currently very few viable Biosystems Engineering programs across Europe. Universities offering undergraduate program in biosystems Engineering in Europe are Technological Institute of Larissa in the Greece, University of Maribor in the Slovenia, UPC-BarcelonaTech in the Spain. University College Dublin in the Ireland offers M.E./M.S./ Ph.D degree in Biosystems and Food Engineering, Wageningen University and Research Centre in the Netherland offers M.S. degree in Biosystems Engineering.

In parallel with this change, the European Society of Agricultural Engineers has also changed the name of Journal of Agricultural Engineering Research as Biosystems Engineering. The topics included in Biosystems Engineering Journal are Automation and Emerging Technologies (AE), Information Technology and the Human Interface (IT), Precision Agriculture (PA), Power and Machinery (PM), Postharvest Technology (PH), Structures and Environment (SE), Animal Production Technology (AP), Soil and Water (SW), and Rural Development (RD).

Table 1. Current Biosystems Engineering Programs in the World (adapted from https://en.wikipedia.org/wiki/Biological_systems_engineering)

Country	**University**	**Faculty**	**Program**	
			Undergrad.	**Graduate**
USA	Auburn University	College of Engineering	Biosystems Engineering	Biosystems Engineering
	Clemson University	College of Engineering, Computing and Applied Sciences	Biosystems Engineering	Biosystems Engineering M.S./Ph.D.
	Florida A&M University	College of Agriculture and Food Sciences	Biological Systems Engineering	-
	Iowa State University	College of Engineering	Biological Systems Engineering	Agricultural and Biosystems Engineering Graduate Program
	Kansas State University	College of Engineering	Biological Systems Engineering	Biological and Agricultural Eng.
	Michigan State University	College of Engineering	Biosystems Engineering	Biosystems Eng.
	North Dakota State University	College of Agriculture, Food Systems, and Natural Resources	Agricultural and Biosystems Engineering	Agricultural and Biosystems Eng.

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergraduate	Graduate
USA	Oklahoma State University	Engineering, Architecture and Technology, Ferguson College of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D.
	University of Kentucky	College of Engineering	Biosystems Engineering	Biosystems and Agricultural Eng. M.S./Ph.D
	University of Nebraska-Lincoln	Institute of Agriculture and Natural Resources	Biological Systems Engineering	Agriculture and Biological Systems Eng. M.S., Biological Eng. Ph.D.
	University of Minnesota	College of Science and Engineering	Bioproducts and Biosystems Engineering	-
	University of Tennessee	Herbert College of Agriculture, in cooperation with Tickle College of Engineering	Biosystems Engineering	Biosystems Eng. M.S./Ph.D

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergrad.	Graduate
USA	University of Wisconsin	College of Agricultural and Life Sciences	Biological Systems Engineering	Biological Systems Eng. M.S./ Ph.D.
	Virginia Polytechnic University	College of Engineering	Biological Systems Engineering	Biological Systems Eng. M.E./M.S./ Ph.D
	Washington State University	College of Agricultural, Human, and Natural Resource Sciences	Biological Systems Engineering	Biological and Agricultural Eng. M.S./ Ph.D.
Canada	University of Manitoba	Price Faculty of Engineering	Biosystems Engineering	Biosystems Eng. M.S./Ph.D.
Brazil	Federal Institute of São Paulo (Campus of Pirassununga), Brazil	Faculty of Animal Science and Food Engineering	Biosystems Engineering	-
	Federal University of Campina Grande,	Center for Sustainable Development of the Semiarid Region	Biosystems Engineering	-
Brazil	University of São Paulo (Campus of Piracicaba)	Luiz de Queiroz College of Agriculture	Agriculture, Forestry, Environment. Management, Food Science and Biological Sciences.	Agricultural Systems Eng.

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergrad.	Graduate
Brazil	São Paulo State University (Campus of Tupã)	Faculty of Science and Engineering	Biosystems Engineering	-
Costa Rica	Universidad de Costa Rica	School of Biosystems Engineering	Agricultural and Biosystems Engineering	Biosystems Eng. M.S.
Greece	Technological Institute Of Larissa	School of Agricultural Technology (Larissa)	Biosystems Engineering	-
Ireland	University College Dublin	UCD School of Biosystems and Food Engineering	-	Biosystems and Food Eng. M.E./M.S./ Ph.D
Slovenia	University of Maribor	Faculty of Agriculture and Life sciences	Biosystems Engineering	-
Spain	UPC-BarcelonaTech	Barcelona School of Agri-Food and Biosystems Engineering (EEABB)	Biosystems Engineering	-
Netherlands	Wageningen University and Research Centre	Wageningen University and Research	-	Biosystems Engineering M.S.
Turkey	Alanya Alaaddin Keykubat University	Rafet Kayış Engineering Faculty	Biosystems Engineering	Biosystems Engineering M.S.

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergrad.	Graduate
Turkey	Aydın Adnan Menderes University	Faculty of Agriculture	Biosystems Engineering	-
	Bilecik Şeyh Edebali University	Faculty of Agriculture and Natural Sciences	Biosystems Engineering	Biosystems Engineering M.S.
	Bingöl University	Faculty of Agriculture	Biosystems Engineering	-
	Bursa Uludağ University	Faculty of Agriculture	Biosystems Engineering	Biosystems Engineering M.S./Ph.D
	Düzce University	Faculty of Agriculture	Biosystems Engineering	-
	Erciyes University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
	Hatay Mustafa Kemal University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
	Iğdır University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
	Kahramanmaraş Sütçü İmam University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
	Kırşehir Ahi Evran University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S.
	Necmettin Erbakan University	Ereğli Faculty of Agriculture	Biosystems Engineering	-
	Malatya Turgut Özal University	Faculty of Agriculture	Biosystems Engineering	-

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergraduate	Graduate
Turkey	Niğde Ömer Halisdemir University	Faculty of Agricultural Sciences and Technologies	Biosystems Engineering	-
	Tekirdağ Namık Kemal University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
	Tokat Gaziosmanpaşa University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
	Van Yüzüncü Yıl University	Faculty of Agriculture	Biosystems Engineering	Biosystems Eng. M.S.
China	Zhejiang University	College of Biosystems Eng. and Food Science	Biosystems Engineering	Biosystems Eng. M.S./Ph.D
Indonesia	Bogor Agricultural University	Faculty of Agricultural Technology	Agricultural and Bio-system Engineering	Agricultural and Biosystem Eng. M.S.
Islamic Republic of Iran	Arak University	Faculty of Agriculture and Environment	Biosystems Mechanical Engineering	-
	Tarbiat Modares University	Agriculture Faculty	-	Biosystem Mechanical Engineering M.S./PhD
	Ferdowsi University of Mashhad	Agriculture Faculty	-	Biosystem Mechanic Engineering PhD
	University of Tabriz	Faculty of Agriculture	Biosystems Engineering	Biosystems Engineering

				M.S./PhD

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergrad.	**Graduate**
Islamic Republic of Iran	Gorgan University of agricultural sciences and natural resources	Water and Soil Engineering Faculty	Biosystems Engineering	Biosystem Engineering M.S.
Sri Lanka	Uva Wellassa University	Faculty of Technological Studies	Biosystems Technology	-
	Wayamba University	Faculty of Agriculture and Plantation Management	Biosystems Technology	Master of Agri-Enterprise & Technology Management M.S.
	Institut Teknologi Sumatera	Faculty of Industrial Technology	Biosystems Engineering	-
Korea	Chungam National University	College of Agriculture and Life Sciences	Biosystems Machinery Engineering	-
	Seoul National University	College of Agriculture & Life Sciences	Biosystems Engineering	Biosystems Engineering M.S./PhD
	Kangwon National University (Chuncheon Campus)	College of Agriculture & Life Sciences	Biosystems Engineering	Biosystems Engineering M.E./Engineering PhD
Indonesia	University North Sumatra	Faculty of Agriculture	Agricultural and Biosystem Engineering	-

Table 1. Current Biosystems Engineering Programs in the World (Continued)

Country	University	Faculty	Program	
			Undergrad.	Graduate
India	Plaksha University	-	Biological Systems Engineering	-
Ethiopia	Hawassa University	Institute of Technology	Biosystems Engineering	-
Kenya	University of Nairobi	Faculty of engineering	Environmental and Biosystems Engineering	Environmental and Biosystems Engineering M.S./PhD
	Jomo Kenyatta University of Agriculture and Technology	School of Biosystems and Environment (SOBEE)	Agricultural and Bio Systems Engineering	Biosystems Structural Engineering M.S./PhD
Uganda	Gulu University	Faculty of Agriculture and Environment	Biosystems Engineering	Biosystems Engineering M.S.

TRANSITION TO BIOSYSTEMS ENGINEERING PROGRAM IN TURKEY

Like other countries in different continents from Asia to America and from Europe to Africa Turkish agricultural faculties also took big steps for transforming agricultural education curriculum during to last two decades. In parallel with the developments in the world, first the "Agricultural Mechanization Board", in the 2nd Education Workshop in Bursa in 2000, decided that agricultural and similar engineering educations were being provided under different names in the USA and EU countries, the most suitable of which was "Biosystems Engineering", and that its subjects included the subjects of the Agricultural Machinery and Agricultural Structures and Irrigation Departments, and therefore a "Biosystems Engineering" program that would be included in both departments and could be accredited at the international level should be opened. Later, in a meeting held in Ankara in 2007, the heads of the Agricultural Structures and Irrigation Departments decided that “within the scope of the restructuring of the Faculties of Agriculture in our country, the Agricultural Structures and Irrigation Department could open a “Biosystems Engineering” Undergraduate Program together with the Agricultural Machinery Department. After these historical decisions, the relevant departments of Uludağ, Kahramanmaraş Sütçü İmam, Tokat Gaziosmanpaşa Universities established the “Biosystems Engineering Department” in 2009 and started to enroll student. Followingly, Namık Kemal, Yüzüncü Yıl, Adnan Menderes, Nevşehir, Adıyaman, Iğdır, Erciyes, Eskişehir Osman Gazi, Düzce and Bozok Universities also established the Biosystems Engineering department. The Biosystems Engineering Department was established with a total of 4 main branches: “Land and Water Resources”, “Agricultural Energy Systems”, “Agricultural Machinery Systems” and “Agricultural Structures”. Currently, 18 biosystems engineering programs are existed out of 36 faculty of agriculture giving education in agricultural area in Turkey. Six of 18 biosystems engineering programs offer only BSc degree, while 4 programs offer M.S. and other 8 programs offer BSc, M.S. and PhD degree. Among these 18 programs, only Bursa Uludağ University Biosystems Engineering Undergraduate Program was accredited by ZİDEK, the local organization that accredits the Education Programs of Faculty of Agriculture, on 28.03.2023(ZİDEK, 2024).

FUTURE PERSPECTIVES

Rapid developments in technology have made it necessary to make changes in agricultural education, as in all other areas. In today's world where input and labor costs are increasing in agricultural production, it is vital to establish an infrastructure for quality and efficient agricultural production, to monitor and analyze each stage of production with appropriate parameters, and to make necessary improvements on production structures depending on the analysis results. Biosystems engineers who can adapt technology to agriculture, have high software knowledge and communication skills, and who will interpret the analysis results correctly and implement the necessary measures will play a key role in achieving this goal. For this reason, educational programs in agricultural faculties must have a flexible structure that allows for continuous improvement. Therefore, it is vitally important to increase the compatibility of programs in Biosystems Engineering, improve their educational content by promoting efforts towards their international accreditation and recognition, and facilitating greater mobility of talented staff, researchers and students.

REFERENCE

Scott, N. R. 2006. DNA of Biological Engineering: An Engineering Discipline? International Journal of Engineering Education 22(1): 9-13.

Stewart, R.E. 1979. Seven Decades that Changed America: A History of the American Society of Agricultural Engineers, 1907-1977, ASAE, St. Joseph Michigan.

Tao, B. Y., D. K. Allen and M. R. Okos. 2006. The Evolution of Biological Engineering. International Journal of Engineering Education 22(1): 45-52.

Young, R.E. 2006b. Comparisons of “Bio”-Type Engineering Undergraduate Curricula from Agricultural, Medical and Chemical Origins. International Journal of Engineering Education 22(1): 14-26.

ZİDEK 2024. List of undergraduate programs accredited by ZIDEK. https://zidek.org.tr/akredite-program-listesi/ Access: 24.12.2024

Comparison of the Efficiency of Some Methods Used in the Estimation of Flood Discharge

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ABSTRACT

There are many empirical methods used for watershed flood discharge calculations in the design of various hydrualic structures, especially dams and ponds. However, different results are obtained from different methods in the calculations. The reason for this is that the methods developed in the USA do not adapt to different regions. For this reason, it is necessary to use the coefficients developed by taking into account the climatic and basin conditions of the region. In this study, the effectiveness of empirical methods such as DSI, Snyder, and Mockus in three sub-watersheds with different sizes in the central district of Edirne province in the Thrace Region were investigated by comparing them with each other. Better results were obtained with Snyder and Mockus methods, in which the coefficients developed considering the regional conditions were used for the watershed flood discharge rate and hydrographs.

Keywords –Watershed, Flood discharge, Flood peak, hydraulic structures, hydrograph,

INTRODUCTION

Water is the most important element for all living things. The efforts of people to benefit from water and to protect it from harm started in the early ages. Rich civilizations were established by utilizing water resources. Today, making use of water resources has become much more important for many reasons.

Global warming and climate change are gradually reducing the available water resources for irrigation in various parts of the world. The Thrace region is the place with the highest industrial and population growth in Türkiye. It has been reported that the population will reach 32.8 million in 2050 and its current resources will be sufficient for drinking and utility water only after 2060 (Istanbulluoğlu et al. 2007). Considering all these, the protection and development of water resources is very important for the future.

Dams and ponds are facilities that store, inflate and channel water to be used for various purposes. Projecting these structures requires estimation of water yield of watershed and flood peak discharges. Currently, these estimates are made using empirical methods developed by the United States (US) Soil Conservation Service (SCS). The compatibility of these methods developed in the US conditions for the conditions of another region is a matter of debate. Spillways are facilities that allow large floods that may occur when dams or pond lakes are full, to the downstream without causing any danger. DSI unit hydrograph, Snyder and Mockus methods are used for dimensioning spillways, the most important unit of dams and ponds, which are water storage structures. There are many studies in the literature on flood discharge estimation around the world (Ozdemir et al. 1978, Demiryurek et al. 1999, Aykanlı (2000), Tekeli and Babayiğit (2000), Oğuz and Balçın (2002), Oğuz and Balçın (2003), Gardner and Muck (2003), Bakır and ark. (2003), Tekeli ve Babayiğit (2002, Ogunlela and Kasali 2002, İstanbulluoğlu et al. 2005, Seong et al. 2008, Salami et al. 2009, Salami et al. 2017. However, different results are obtained from different methods in calculations made in the same field. The reason for this is that the methods developed in the USA are not adapted to different regions.

The aim of this study is to determine which empirical method should be used to design a large enough spillway to transfer excess water safely when the dams or ponds to be built in the rural area of Edirne province in the Thrace Region are filled with incoming precipitation. For this, three sub-watersheds of different sizes were selected as the research area and calculations were made with DSI, Snyder and Mockus methods.

MATERIAL and METHOD

Material

The investigated watersheds are located 10 km away from the city center of Edirne, in the Thrace Region of western Türkiye. The watershed, whose altitude is between 55 -154 m above sea level, are between 26°40'- 26°45' east longitudes and 41°35'- 41°45' north latitudes. The watershed consist of three sub-watersheds of different sizes, these are the Subaşı, Musabeyli and Kumdere watersheds. These watersheds are shown in Figure 1.

Figure 1: Research area

Edirne province, in the Thrace Region, surrounded by the Yıldız (Istranca) Mountains to the north, is generally under the influence of the continental climate. Winters are cold and rainy, summers are dry and hot. Almost all of the precipitation in the region is in the form of rain. Again, according to long-year observation data; temperature is 13.8 oC, total precipitation is 582 mm, relative humidity is 69%, total evaporation is 922.5 mm and wind speed is 1.7 m/s. The first frost occurs in the second half of October, and the last frost occurs in the last week of April (DMİ, 1984; 2011). The majority of the basin soils that are the subject of the research are Limeless Brown, and only a few of them are made up of Vertisol large soil groups. They are medium sloping (6-12%) and deep soils with corrugated topography. Watersheds are third class land. In the whole area, fallow-free dry farming is practiced using the wheat-sunflower alternation system.

Watershed characteristics are the most important parameters, especially when comparing one basin with another. These are geomorphological such as area, shape, slope; hydrogeological such as stream form, infiltration; pedological characteristics such as soil physics and vegetation. Some of these parameters, such as area, shape and slope, are fixed and do not change over time or can be taken as constant because they change over very long periods of time. Others change over time, such as the change of vegetation with the seasons, the change of infiltration capacity according to some factors. Some basin characteristics are shown in Table 1.

Table 1: Some watershed characteristics in the research area

Watershed characteristics	Watersheds		
	Subaşı	Musabeyli	Kumdere
Area, A (km^2)	4,4	10,2	27,3
Perimeter, P (km)	9,5	16,8	31,3
Length, L_H (km)	3,5	7,4	13,0
Width, W_H (km)	2,0	2,0	4,0
Maximum height, hmax (m)	154	154	154
Lowest height, hmin (m)	115	85	55
Relief, r (m)	39	69	99
Relative relief, r_n (%)	0,41		
Direction	North-South	North-South	North-
Average height of the basin, hort (m)	140		South
Median height, h_{med} (m)	135		
Mean slope, S_H (%)	4,0		
Figure index depending on the main	2,7		
stream path, S_1	3,6	7,8	
Length of main stream road, L (km)			14,5
The length of the basin center of gravity	1,9	3,7	
to the basin exit point, L_c (km)	1,3		8,4
Main stream road profile slope, S_s (%)	0,9	0,8	
Main stream path harmonic slope			0,7

In order to determine the location and time distribution of precipitation, pluviographs were placed at three different locations and heights at the upper limit of the watershed (150 m), in the middle of the watershed (145 m) and at the watershed outlet (115 m) and observed. For flow observations, a triangular channel with a slope of 1/5 was constructed at the watershed outlet (110 m high). A flow meter (limnigraph) was placed in the resting pool, which is connected with the channel by the channel, right next to the channel construction, and the time distribution of the flow passing through the stream bed was measured with the help of the channel. In the study, the measurement values recorded from the mentioned precipitation and flow stations between 1985-1999 (15 years) were used (Bakanoğulları and Akbay, 2000).

Method

In the calculation of water yield to be obtained from the study watersheds; besides the direct runoff values measured in the Subaşı sub-watershed, the following empirical equations are used.

Runoff measure

For this purpose, a limnigraph was placed in the extinguishing pool connected to the 1/5 inclined triangular channel built at 110 m height at the outlet of the Subaşı watershed, and the time distribution of the flow passing through the stream bed was measured. Then, the curves in these measurement records were analyzed on a daily basis and direct flow values were obtained (Bakanoğulları and Akbay, 2000).

DSI Synthetic method

This method, which is used by the State Hydraulic Works (DSI) in Türkiye, was developed by the United States (USA) Soil Conservation Service (SCS). In this method, the dimensionless unit hydrograph is used in the drawing of the synthetic unit hydrograph. The equation for calculating the flood peak discharge for the two-hour rainfall excess is shown below. (Soil Conservation Service, 1956; 1971; Linsley et al., 1988).

$$Q_p = Ah_a q_p 10^{-3} \tag{1}$$

In this equation; Q_p is the flood peak discharge rate (m^3 s^{-1} mm) of the two-hour excess precipitation; A, basin area (km^2); ha, the runoff height (mm) from the watershed. The runoff height is found as a result of the runoff curve number, in which the watershed is determined by considering the soil, land use, vegetation, cultivation method and soil protection measures. q_p is the flow rate from each square kilometer of the watershed (L s^{-1} km^2 mm) when the flood discharge reaches its highest (peak) value after an excess of

precipitation that lasts for two hours and is accepted to produce 1 mm flow over the watershed.
If an operation is performed with this method, first the main stream path of the basin is divided into ten equal parts along its length, and after the slope of each part is found, its harmonic slope is found with the following equation.

$$S = \left(\frac{P}{\sum \frac{1}{\sqrt{Si}}} \right)^2 \tag{2}$$

In the equation, S is the harmonic slope of the main stream road; P is the number of divergences of the main stream road and S_i is the slope of each portion of the main stream road. Then, by calculating E= L Lc $S^{-1/2}$ value and using this value and basin area, unit flood discharge rate q_p can be found with the help of Equation 3.

$$q_p = \frac{414}{A^{0.225} E^{0.16}} \tag{3}$$

In this equation, q_p is the unit flood peak flow rate (L s^{-1} km^2 mm) of the two-hour excess precipitation; A is the catchment area, (km^2) and E is a coefficient equal to Lc $S^{-1/2}$. The total water volume (m^3) resulting from the floods is calculated from the equation below.

$$\boldsymbol{V = A h_a 10^3} \tag{4}$$

Hydrograph base time (seconds), $T = 3.65 \left(\frac{V}{QP} \right)$ and hydrograph rise time (seconds),$T_p = 744 \left(\frac{A}{QP} \right)$ or $T_p = \frac{T}{5}$ are calculated using the equations.

Snyder method

With this method, a required synthetic unit hydrograph of a known-duration rainfall excess is calculated following the procedures below (Chow et al., 1988; Linsley et al., 1988). With this method, the lag time of the standard unit hydrograph is calculated as the first operation for a required synthetic unit hydrograph of a known-duration rainfall excess by the following equation.

$$t_p = 0.75 C_t (L L_c)^{0.3} \tag{5}$$

In equation; t_p is the lag time (hours) of the unit hydrograph; C_t, a coefficient dependent on land conditions (2.2 with slight slope, 2.0 with moderate slope, and 1.8 with high slope); L is the length of the basin main stream route in kilometer (km) and L_c is the distance in kilometer (km) from the outlet to a point on the stream nearists the centroid of watershed area. The above is for hydrograph lag time t_p = 5.5 tr. In this case, tr = t_R and q_p = q_{pR}. However, in a different case, that is, the lag time of a synthetic unit hydrograph for a certain period of excess rainfall is calculated with the following equation.

$$T_{pR} = t_p - 0.25 \ (t_r - t_R) \quad \text{or} \quad t_{pR} = t_p + 0.25 \ (t_R - t_r) \qquad (6)\ (7)$$

Where; t_{pR} is the lag time (hours) of the unit hydrograph of required duration and t_r is the standard excess rainfall time (hours). This value is calculated from the equation $t_r = t_p\ 5.5^{-1}$ obtained from the condition $t_p = 5.5\ t_r$. t_R is the rainfall excess time (hours) of the unit hydrograph with the required duration. The unit flood peak flow rate from the basin, in case the runs are tp = 5.5 t_r,

$$q_P = 2.75\left(\frac{C_P}{t_P}\right) \qquad (8)$$

It is calculated with the equation. However, the flood peak flow rate of a synthetic unit hydrograph required for a certain period of excess rainfall is as follows:

$$q_{PR} = q_P\left(\frac{t_P}{t_{PR}}\right) \quad \text{or} \quad q_{PR} = 2.75\left(\frac{C_P}{t_{PR}}\right) \qquad (9)\ (10)$$

It is calculated with the equation. In equality; qp is the flood peak discharge rate ($m^3\ s^{-1}\ km^2$ cm) for the unit precipitation excess height per unit area; Cp is a coefficient depending on soil conditions (sandy 0.5, sandy-clay 0.6, heavy clayey or rocky 0.7) and qpR is the flood peak flow rate ($m^3\ s^{-1}$ km^2 cm) for a certain period of unit rainfall excess height per unit area. Flood peak discharge rate for a certain period of excess precipitation is calculated with the following equation.

$$Q_{PR} = q_{PR} h_a A \qquad (11)$$

In equality; QpR, flood peak discharge rate ($m^3\ s^{-1}$) from the basin; ha is the surface runoff height (cm) consisting of the basin and A is the basin area (km^2). ha is the runoff height. After the specified calculations, it is started to draw the synthetic unit hydrograph with the desired time. For this, the following equations are used. For the base time (hours) of the unit hydrograph,

$$t_b = \frac{5.56}{q_{PR}} \qquad (12)$$

For certain widths (hours) of the unit hydrograph,

$$W_{50} = 2.14 q_{PR}^{-1.08} \qquad W_{75} = 1.22 q_{PR}^{-1.08} \qquad (13)\ (14)$$

In equality; W50 and W75 are unit hydrograph widths (hours) corresponding to 50% and 75% of the flood peak flow rate.

In addition, a solution has been made with the modified Snyder method, which uses the coefficients obtained for the region from the results of multi-year direct measurements and observations made in the sub-basins of the Thrace Region in Türkiye. The coefficients used here are Ct = 1.41, Cp = 0.56 for the suggested mean and Ct = 0.75, Cp = 0.78 for the maximum (Istanbulluoglu et al., 2004).

Mockus method

In this method, the unit hydrograph is assumed to be a triangle. Triangular hydrographs provide results that are as reliable as curved hydrographs. It is applied for basins with a accumulation time of up to 30 hours (Chow et al., 1988).

The process of drawing a synthetic unit hydrograph with the Mockus method begins with the calculation of the flood accumulation time by using the main stream path length and slope of the basin.

$$T_c = 0.00032\,\frac{L^{0.77}}{S^{0.385}} \text{ (In rectangular basins)} \qquad (15)$$

$$T_c = \frac{L^{1.15}}{3100 \cdot H^{0.385}} \text{ (In circular basins)} \qquad (16)$$

In equality; Tc, flood collection time (hours); L is the main stream path length (m); S is the main stream road slope (m) and H is the difference between the upstream and downstream heights of the basin (m). Of these, it is recommended to use if the shape of the basin resembles a rectangle, and the latter resembles a circle. Detection of the shape of the basin being rectangular or circular; It is calculated from the number (Rd) obtained as a result of the ratio of the actual basin area to the circle area obtained from the basin circumference value. If the Rd number is between 0.6 and 0.7, it is accepted that the shape of the basin resembles a circle. In other cases, it is accepted that the shape of the basin resembles a rectangle.

Then other hydrograph elements are calculated;

Time of excess rainfall, $t_r = 2\sqrt{Tc}$,

Lag time, $t_P = 0.6\ T_c$

The time of rise of the hydrograph, $T_p = \sqrt{Tc} + 0.6\ T_c$ or

$T_p = 0.5\ t_r + 0.6\ T_c$

$T_p = 0.6\ T_r$,

$T_p = 3/8\ T_b$

The time of drawing of the hydrograph,

$T_r = 1.67\ T_p$ ($\underline{1.67 = H}$) or $T_r = 5/8\ Tb$

The base time of the hydrograph,

$T_b = 2.67\ T_p$ or $T_b = T_p + T_r$

In equality; T_r, duration of excess precipitation (hours); T_p is the flood lag time (hours), in other words, the time difference between the precipitation excess hyetograph center and the unit hydrograph flood peak flow rate; T_p is the rise time (hours) of the flood hydrograph; T_r is the retreat (descend) time of the flood hydrograph (hours) and T_b is the total base time (hours) of the flood hydrograph. The unit flood peak flow rate from the basin is calculated with the following equation; ,

$$Q_p=0{,}208\ A\ T_p \quad (\underline{0{,}208=K}) \tag{17}$$

In equality; Q_p is the unit peak peak flow rate (m^3s^{-1} mm) and A is the catchment area (km^2). Then, the total peak flow rate of the basin is obtained from the equation $Q_p = q_p \times h_a$. Here, ha is the runoff height in the basin (mm). Finally, using the data calculated above, the synthetic triangular unit hydrograph is plotted. The unit hydrograph obtained here is a unit hydrograph of the tr precipitation excess period. The Q_P value found is also the flood peak discharge rate of the tr excess precipitation period. However, there may be basin conditions where the excess precipitation period cannot be taken as $t_r = 2\sqrt{}T_c$ and can be taken differently. In addition, a solution has been made with the modified Mockus method, in which the coefficients obtained for the region from the results of multi-year direct measurements and observations made in the sub-basins of the Thrace Region in Türkiye are used. Here, the coefficients are used as H = 1.29, K = 0.190 for the suggested mean and H = 2.40, K = 0.247 for the maximum (Istanbulluoglu et al., 2004).

RESULTS AND DISCUSSION

Basin Precipitation Characteristics

In the light of the values recorded from the precipitation gauges positioned to represent the research basins, the average of the multi-year total (1985-1999) precipitation values is 609,6 mm. Precipitation fell mostly in autumn and winter.

Basin runoff characteristics

When the total flow values for many years (1985-1999) are examined, the highest flow is 130.05 mm in 1999. The average flow amount is 21.30 mm. Flow is highest in autumn. In terms of basin precipitation-flow relationship, no relationship was observed in periods (years, months). Since the development of the basin vegetation has increased, the amount of runoff has decreased significantly in the spring months.

Amprical runoff methods

DSI, Snyder and Mockus methods are used for dimensioning spillways, the most important unit of dams and ponds, which are water storage structures. Spillways are facilities that allow large floods that may occur when dams or pond lakes are full, to the downstream without causing any danger. The capacity to be given to them is determined by performing "flood routing". In this, it is necessary to know the "volume-area" and "discharge" curves of the dam lake and the "flood hydrograph" (Şentürk, 1988). In practice, it is very important that the flood hydrographs obtained are reliable. This is possible with hydrographs obtained by using directly measured precipitation and flow values. However, this is often not the case in practice.

For this reason, it is necessary to use the mentioned empirical methods. In Türkiye, DSI and Snyder synthetic hydrograph methods are used for dams and ponds, while Mockus method is used for designing ponds and other small water structures. The peak flood discharges obtained for the basins in the research area are given in Table 2 below.

Table 2: Flood peak discharges that may occur according to DSI, Snyder and Mockus methods

Watersheds	Methods (m^3/s mm)		
	DSI	Snyder	Mockus
Subaşı	0.658	0.238	0.572
Musabeyli	1.016	0.395	0.907
Kumdere	1.695	0.702	1.527

As can be seen, approximate flow rates were obtained from DSI and Mockus methods. The Snyder method was found to be very low compared to the others. This is a very important issue that needs to be taken into account by implementing organizations. The reason for this difference between the methods is that the coefficients used in the equations included in each method do not fully reflect the local climate and basin conditions. In order to eliminate this negativity, it was calculated by using the direct surface flow values measured in different basins in the Thrace Region by Bakanoğulları and Akbay (2000), and again Istanbulluoglu et al. (2004; 2005) using the coefficients suggested for the Snyder and Mockus methods, the flood peak discharge rates obtained are shown in Table 3. Istanbulluoglu et al. The fact that the flow values obtained by using the coefficients suggested by (2004; 2005) are higher than the current practice and those calculated by Bakanoğulları and Akbay (2000) is due to the risk.

Table 3: Flood peak discharge according to Snyder and Mockus methods

Watersheds	Methods (m^3/s mm)					
	Snyder method			Mockus method		
	Practice[1]	Calculated[2]	Suggested[3]	Practice[1]	Calculated[2]	Suggested[3]
Subaşı	0.238	0.294	0.634	0.572	0.523	0.679
Musabeyli	0.395	0.499	1.111	0.907	0.828	1.077
Kumdere	0.702	0.898	2.083	1.527	1.394	1.813

[1]: Data applied to date by relevant institutions.

[2]: Bakanoğulları and Akbay, 2000.

[3]: Istanbulluoglu et al., 2004; 2005.

As can be seen from Table 3, Istanbulluoglu et al. (2004) used the coefficients suggested by the hydrographs, although the flow values were higher than the others, the hydrograph descent curve was also of very short duration. This means that too much flow will be diverted from the spillways in a short time. In other words, the dam or pond will require the spillways to be built larger than their planned size to date. However, this also allows these structures to have smaller storage volumes.

CONCLUSION

A long annual average (1985-1999) total precipitation of 609.6 mm fell in the research basins. The runoff was 21.3 mm. The basin surface runoff coefficient was obtained as 0.035. This coefficient was much smaller than 0.13 (Bayazıt, 1995), which is the runoff coefficient of the Meriç-Ergene basin where the basin is located.

Different results were obtained from each of the empirical methods such as DSI, Snyder and Mockus used for flood discharge calculation in the sub-basins of Edirne province in the Thrace region. Among these, DSI and Mockus methods gave partially close values, but Snyder method gave less than half.

As a result of the calculations made by using the coefficients in the Snyder and Mockus methods and those suggested by Istanbulluoglu et al. (2004; 2005) for the research area, the values of both methods gave close results. However, the obtained values have been greater than those calculated in practice so far.

The fact that the watershed surface runoff coefficient is very small requires that the falling precipitation be stored where it falls. This requires the water storage structures to be built in the region to be planned on the basis of the sub-watershed.

The new coefficients suggested for the Snyder and Mockus methods should be used in the planning of various water structures and their spillways to be built on rivers. The flood discharge rates obtained with the new coefficients will be larger than those calculated so far, leading to larger planning of spillways. This will provide more life and property safety, despite an additional cost.

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REFERENCE

Aykanlı, N., 2000. Balıkesir-Bigadiç Kocadere Havzası Yağış-Akış Karakteristikleri. KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 117, Ankara.

Bayazıt, M., 1995. Hidroloji. İstanbul Teknik Üniversitesi, İnşaat Fakültesi yayınları, 165, İstanbul.

Bakanoğulları, F. and Akbay, Ş., 2000. Edirne-Merkez Kumdere Havzası Yağış ve Akım Karakteristikleri (Ara Raporu 1985-1999). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı yayınları, 117, Ankara.

Bakır, H., Coşkun, T., Birhan, H., Daşçı, E., Özlü, A., Çakal, MA., Sevim, Z. and Öztaş, T., 2003. Erzurum-Ilıca Sinirbaşı Deresi Havzası Yağış ve Akış Karakteristikleri (Ara Rapor 1997/2002). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 124, Ankara.

Chow, VT., Maidment, DR. and Mays, LW., 1988. Applied Hydrology. McGraw-Hill Press, New York, 557 pp.

Demiryürek, M., Tongarlak, E. and Okur, M., 1999. Konya-Çiftliközü Karabalçık Deresi Havzası Yağış ve Akış Karakteristikleri (Ara Rapor 1979-1999). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 115, Ankara.

DMİ, 1984. Ortalama, Ekstrem sıcaklık ve yağış değerleri Bülteni. Başbakanlık Devlet Meteoroloji İşleri Genel Müdürlüğü yayınları, 678 s., Ankara. DMİ, 2004. Bölge İlleri Ortalama ve Ekstrem Kıymetler İklim Verileri. Devlet Meteoroloji İşleri Genel Müdürlüğü Bültenleri, 12 s, Ankara.

Gardner, CMK. and Muck, DN., 2003. Deriving Unit Hydrographs for Small Catchments. Journal of the Chartered Institution of Water and Environmental Management, 17(4): 245-250.

Istanbulluoglu, A., Konukcu F. and Kocaman I., 2004. Precise Determination of Turkish Spillway Sizes from Synthetic Unit Hydrographs to Prevent Flood Damage. ACTA Agriculturae Scandinavica Section B. Soil and Plant Science, 54(3): 1-8.

Istanbulluoglu, A., Konukcu F. and Kocaman I., 2005. Determination of the Project Parameters for the Small Earth Reservoirs to be Built in the Sub-Basins of Thrace Region. International Symposium on Water for Development

Worldwide, General Directorate of State Hydraulic Works (DSI), Istanbul, 24-35.

Istanbulluoglu, A., Konukcu, F., Kocaman, I., and Gocmen, E. (2007). Forecasting drinking and household water requirement of the Thrace region. *Journal of Tekirdag Agricultural Faculty (TÜRKİYE)*, *4*(2).

Linsley, RK., Kohler, MA. and Paulhus, JLH., 1988. Hydrology for Engineers. McGraw-Hill, London, 492 pp

Oğuz, İ. and Baçlın, M., 2002. Tokat-Zile Akdoğan Deresi Havzası Yağış ve Akış Karakteristikleri (Ara Rapor 1987-2001). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 121, Ankara.

Ogunlela, A. O., and Kasali, M. Y. (2002). Evaluation of four methods of storm hydrograph development for an ungauged watershed. *Nigerian Journal Technology Development*, *2*, 25-34.

Oğuz, İ. and Baçlın, M., 2003. Tokat-Uğrak Havzası Havzası Yağış ve Akış Karakteristikleri (Ara Rapor 1977-2002). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 124, Ankara.

Özdemir, H., 1978. Uygulamalı Taşkın Hidrolojisi. Devlet Su İşleri Genel Müdürlüğü yayınları, Ankara.

Salami AW, Bilewu SO, Ayanshola AM, and Oritola SF. Evaluation of synthetic unit hydrograph methods for the development of design storm hydrographs for Rivers in South-West, Nigeria. J Am Sci 2009; 5 (4): 23-32

Salami, A. W., Bilewu, S. O., Ibitoye, B. A., & Ayanshola, M. A. (2017). Runoff hydrographs using Snyder and SCS synthetic unit hydrograph methods: A case study of selected rivers in south west Nigeria. Journal of Ecological Engineering, 18(1).

Seong, C. H., Kim, S. M., and Park, S. W. (2008). A comparative study of unit hydrograph models for flood runoff simulation at a small watershed. *Journal of the Korean Society of Agricultural Engineers*, *50*(3), 17-27.

Şentürk, F., 1988. Barajların Projelendirilmesinde Hidrolik Esaslar. Devlet Su İşleri Genel Müdürlüğü Yayınları, s. 628, Ankara.

Soil Conservation Service (SCS), 1956; 1971. Hydrology. National Engineering Handbook, Supplement A, Section 4, Chapter 10, USDA, Washington D.C.

Tekeli, Yİ. and Babayiğit, HG., 2000. Ankara-Haymana Çatalkaya Deresi Havzası Karakteristikleri (Ara Rapor 1994-1999). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 117, Ankara.

Tekeli, Yİ. and Babayiğit, HG., 2002. Ankara-Yenimahalle Güvenç Havzası Karakteristikleri (Ara Rapor 1984-2001). KHGM Toprak ve Su Kaynakları Araştırma Sonuç Raporu, APK Dairesi Başkanlığı, 121, Ankara.

Work Accidents and Precautions in Agriculture

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ABSTRACT

Events that occur in unsafe working environments are called accidents. The way accidents occur; It occurs with the effects of human, machine and environment trio. The rate of accidents caused by human errors varies. Occupational accidents and occupational diseases are one of the main problems when viewed from the producer side. Agriculture is a sector that feeds people and provides raw materials to industrial branches and involves various risks due to its nature. Sustainability at every point of production and especially in agricultural production is important for people to continue their lives. The continuity of production in agriculture depends on the protection of the health of workers in this sector. Unfortunately, many deaths, injuries and material losses occur in these areas every year as a result of occupational accidents and occupational diseases. Although efforts are made to prevent occupational accidents and occupational diseases, it is not possible to avoid accidents. Accidents develop under the influence of human factors, environmental conditions and machine structural status. While threatening the health of employees, it also negatively affects the production process operations.

In this study, in addition to the occupational accidents occurring in the agricultural sector in the world and in Turkey and their causes, it is aimed to provide the parties with technical information about the hazards and precautions that can be taken in agricultural activities occurring in production areas in Turkey and the prevention of occupational accidents. It has been observed that approximately half of the world's population works in agriculture and a significant portion of occupational accidents occur in this agricultural sector. In order to minimize possible accidents in this sector, it is tried to list the measures and precautions that can be taken by the relevant stakeholders, those concerned, manufacturer machine manufacturers.

Keywords – Occupational accidents, agriculture, machinery, occupational safety, risks

INTRODUCTION

Today, the rapid increase in the world population and the rapid decrease in agricultural land led to a serious crisis in food supply. The rapid increase in the world's population, climate change, drought and erosion, as well as the reduction in agricultural land, have become a serious problem threatening food security. This situation exacerbates the already existing problems of malnutrition and hunger, especially in developing countries. While the world population has doubled in the last 50 years, agricultural land has decreased by 10%. This situation seriously threatens food security. Agricultural land, which was abundant in the past, is now rapidly disappearing due to concretization and industrialization, creating a serious food problem for future generations. To overcome this problem, solutions such as the spread of sustainable agricultural techniques, the use of genetically modified crops and the reduction of waste should be emphasized.

According to data from organizations such as the World Health Organization (WHO) and the International Labor Organization (ILO), the agricultural sector accounts for a significant proportion of occupational accidents. Especially in developing countries, agricultural workers are at higher risk. Accidents such as tractor overturns, entrapments, and sharps injuries are among the most common types of accidents.

In Turkey, agricultural accidents constitute a significant portion of occupational accidents. This is particularly evident in regions where agriculture is intensive. Although there is some information on occupational accidents in the agricultural sector in the data of institutions such as the Turkish Statistical Institute (TurkStat) and the Social Security Institution (SSI), there are some question marks about the scope and accuracy of these data.

All activities in agricultural production require either labor or agricultural machinery. One of the biggest problems faced by the labor force is the issue of occupational health and safety. There are risks at every stage of production. These risks need to be revealed and different occupational health and safety measures are needed.

For underdeveloped or developing countries the problems related to occupational accidents and occupational safety have to be taken into account. Many reports, analyses and reports have shown that agriculture is one of the most dangerous sectors. In this context, a developing country has to develop and grow its agricultural sector in order to keep its economy alive. The three basic needs of humanity are food, clothing and shelter. Dangerous processes manifest themselves in these areas during this period of time.

As a result of the increasing population in the world, larger agricultural areas are needed to grow crops. However, with the opening of these areas to housing and industrial zones, it is necessary to produce in fewer, limited areas and to meet the nutritional and other needs of a larger population. While agricultural areas have been decreasing over the years, in order to feed the growing population, higher quantities of products are needed from the unit area. Depending on the plant pattern and diversity, it is provided by the use of different types of machinery. During the use of machines, there is an increase in accidents that occur in agriculture during production.

Agricultural tools and machinery used during agricultural activities constitute the main cause of accidents in this sector. Tractors remain the most important power source for agriculture. Since many tools and machines used in agriculture are driven by the tractor, the tractor is an indispensable tool for the application of modern agriculture and techniques. Technological changes and developments in agriculture are taking place rapidly like other sectors. Technological advances are not only related to the power of the tractor and the torque it develops, but also to occupational safety measures to provide safe driving and control systems for the driver. In addition to digital agricultural systems, autonomous vehicles will soon appear in agricultural areas.

Agriculture is a natural process in all seasons. It must be carried out in all weather conditions, the materials such as soil, plant, fertilizer, irrigation, chemical pesticides, etc. that are processed vary, and the driver must create a comfortable and safe working environment for the operator. Population in the world and in Turkey has been increasing over the years, hence the need for food has also been increasing. This situation causes agriculture to become a strategic sector in terms of both nutrition and employment. By ensuring occupational safety in agricultural work, accidents can be reduced. By increasing the expected efficiency of the machine and reducing the lost time, it will be possible to reduce the economic cost of the work. If occupational safety is ensured, it is possible to reduce accidents, reduce lost time and thus increase machine efficiency. If precautions are taken, damage to the machine will be prevented as well as the safety of the driver's life safety. There will be many reasons why accidents and occupational diseases in agriculture will occur over time. It is likely to increase accidents, especially the tractor, which is used as the main power source in agriculture, and the use of the power taken from the tractor in the operations of the agricultural machinery connected to it. Most of the accidents in agriculture are caused by the tractor, and about half of them are accidents caused by tractor overturning. We can clearly see this from the studies of many researchers in these fields (Yıldırım, and Altuntaş, 2015; Özkan and Dilay, 2020). Research shows that accidents are usually caused by carelessness and ignorance. In order to overcome this deficiency, the users and operators using these machines must be well trained. The rapid development of technology also manifests itself in these areas. The use of equipment and complex designs, the tendency of these operators and their lack of practice make the adaptation process difficult. Many studies have been conducted in this field, and the common result is that working with tractors and agricultural machinery connected to tractors still continues to be an important risk (Peker and Özkan, 1994; Alçayır, 2018; Akbolat, 2007; Tiwari et al., 2002). If an operator takes good care of the machine he is using, he fulfils the safety requirements to a great extent. Otherwise, if there is insufficient maintenance and at the same time the knowledge and skills of the driver are not sufficient, he is always likely to face danger. Uncontrolled behavior while operating a tractor is the main cause of many fatalities. A training on a machine allows to learn all the components of the machine and to form a habit, but with different machines, all control components may not work in the same way and in the same direction. For this reason, the operation of a new machine by handing it over to an operator who has no experience and does not know it well may have risks and dangerous aspects in terms of life and property safety. Damage to a used machine due to an accident, repair and maintenance costs, as well as the wage costs to be spent when we have to do the same work with another machine, taking into account the wage costs to be spent, may adversely affect the operating efficiency due to affecting the balance of operating income and expenses.

In order to make accurate analyses of the causes of accidents, it is necessary to investigate and analyse both accidents and non-accident conditions. Only with a two-sided perspective can more realistic steps be taken. In the agricultural sector, which faces occupational accidents and occupational diseases, the rate of accidents is in the first place together with the mining sector and the construction sector. This situation continues to be an important problem all over the world. At the beginning of the causes of occupational accidents in agriculture, the fact that agricultural activities take place in open lands, the low level of education of the employees, the lack of adequate working environment and environment, nutrition and resting environments, and the obligation of employees to work in more than one job depending on the economic situation (Gügerçin and Baytorun, 2018). Agricultural activities should not only be thought of activities such as sowing, planting, fertilizing or irrigation in the open air. In addition, it is seen that those working in warehouses, warehouses, storage of agricultural products, transportation and transmission facilities, and workshops where processing is carried out are also in the serious risk group.

POSSIBLE WORK ACCIDENTS IN AGRICULTURE

Machine-related accidents: Tractor overturning, jamming, crushing, falling, misuse, lack of timely maintenance, lack of adequate service facilities for repair, uncontrolled and careless use of equipment (Figure 1). Inadequate maintenance and repair of the existing machines in the machine park.

Figure 1: Accident Occurring as a Result of Tractor Overturning (Anonymous, 2022).

Accidents caused by falls: It can be seen in fruit picking, while creating haystacks, during work on slippery surfaces, while carrying live animals on agricultural carts and tractors. As a result of falls, tripping or entanglement in moving parts, crushing, cutting, jamming in free rotating parts; as a result of unsafe work clothes, it can lead to limb losses and injuries due to wraps (Figure 2).

Figure 2: Personnel Transportation by Agricultural Trolley and Accident Risks Due to Falling (Özay, 2022).

Accidents related to animals: Animal attacks, animal bites, kicking and crushing during milking processes, and other risks in the fight against pests. The situation caused by animal risks will bring dangers in the form of kicking, biting, squeezing, hitting a hard place during the obligation to work close to animals. On the other hand, it causes the transmission of pests such as viruses, bacteria and parasites from animals to workers through contact or respiratory tract. First aid personnel and other personnel should undergo training against possible animal bites, stings and attacks.

Accidents in agricultural control: A number of chemicals used for the cultivation of agricultural products will sometimes cause poisoning and sometimes provide the grounds for the development of cancer. The effects of hazardous gases such as veterinary drugs, exhaust fumes from vehicles, methane, ammonia, which are emitted or accumulated in the environment in barns and poultry houses, on living things, employees should act more carefully. Risks arise as a result of incorrect application of pesticides on the plant, direct contact of pesticides with the body and skin, poisoning by respiratory tract, and not applying them at the appropriate time in accordance with environmental conditions. Wounds and bruises on the respiratory system and skin are caused by the effect of pesticides and fertilizers used in agricultural control.

Accidents caused by environmental factors: Long periods of working in hot and cold environments, the danger of heat stroke and frostbite, the sun's rays affecting the operator, outside precipitation, dust particles and foreign objects in use with a tractor without a cab, high amounts of noise level in the working environment reduce working efficiency. Especially with the increase in temperatures in the summer months, it is imperative to fight in a timely manner to eliminate insects that carry and transmit microorganisms such as mosquitoes, houseflies, fleas, ticks, viruses and parasites, which cause an increase in temperatures.

RECOMMENDATIONS TO PREVENT WORK ACCIDENTS

Training on safety: Training and demonstration work on occupational safety of employees in this agricultural activity, revealing the risks on tools and machines, providing technological training to tool and machine manufacturers, providing information studies by occupational safety and experts during periods when activities decrease, protecting young workers in the agricultural sector or keeping them away from these areas, revealing suitable environments for improving the occupational safety and social life of seasonal agricultural workers, ensuring the occupational safety of women workers

Personal protective equipment: Provision of work clothes suitable for work, helmet, gloves, work shoes, mask and ear plugs should be provided.

Ergonomic machine design: The agricultural sector is an area where people are needed the most in the production process. As in every labor-demanding line of work where man-made features and natural conditions are intertwined, it is also needed in the agricultural sector. Every process and design made in ergonomic terms should be carefully implemented by machine manufacturers in every aspect. Employees in the agricultural sector work for long periods of time and in positions that are not suitable for their body condition. The personal characteristics of the employees such as gender, age, education level, physical characteristics, temperament, attitudes and behaviours vary. Working tools and mechanical tools should be below shoulder level, and ergonomically appropriate handles and accessories should be available for the hand tools used. Excessive exposure to vibration in manual work leads to impaired blood circulation, nerve, bone and joint disorders, and as a result, health problems related to musculoskeletal-circulatory systems.

Tractors with cabins or safe steel construction against tipping over provide convenience for the driver. Environmental conditions such as dust, noise, rain, etc. are important for driver comfort. Designing equipment with these features will offer advantageous sales opportunities for manufacturers.

It is a fact that noise and vibrations caused by heavy loads, tools and machinery will cause health problems for workers in the long term. It is not possible to intervene quickly and effectively in case of health problems that may occur. If the necessary measures and precautions are taken and the training of the employees is done in a practical way as well as theoretical knowledge, it will be possible to eliminate the risks that may occur ergonomically.

Machine maintenance: Agricultural tools and machinery should be checked regularly according to the working hours and conditions; maintenance should be carried out without interruption and maximum sensitivity should be shown to other measures for a safe working environment. If necessary, maintenance and repair catalogs should be made if it is possible to be done with the facilities of the enterprise, otherwise support should be obtained from technical services.

Safety of the work environment: Work areas should be kept neat and tidy, made of materials that will not cause slippery floors, appropriate lighting apparatus for regional lighting, sufficient amount of light should be provided.

Emergency Action Plans: The planning to be made in all kinds of emergency situations should be clearly prepared and should be within the necessary legislation for informing employees and preparing emergency action plans.

Safe use of pesticides: When using pesticides, the instructions on the label should be strictly followed, personal protective clothing should be worn and respirators and apparatus should be used when spraying.

Reducing the physical load: Correct techniques should be used when lifting heavy loads, and mechanical tools should be preferred when labor is required.

Regular Health Checks: Employees should undergo regular health checks at regular intervals and if health problems are detected early, the treatment process should be started without delay. In this context, early detection of health problems helps the treatment to be done in a short time.

CONCLUSION

The fact that accidents occur in areas that are difficult to control and far from supervision makes the reduction process difficult. Occupational safety in rural agricultural work allows workers to work in a healthy and safe environment. It reveals practices that will prevent damage to the devices and tools used here. The costs of accidents that may occur due to imprudence, carelessness and negligence can be great. More than material losses, moral losses cause negativities in people. No matter how expensive a damaged machine is, it can be replaced. However, it is never possible to replace human and human health. In this respect, it is extremely important to strictly follow the rules set for occupational safety in order not to encounter irreparable sad developments in the future.

People and employees who will use agricultural tools and machinery should receive training and learn fully and completely from the practices related to the use of tools and machinery. Minors, undocumented and unqualified persons should not use agricultural tools and machinery. Care should be taken to ensure that young children are not involved in agricultural activities. When evaluated in terms of gender, age, education and demographic variables, it can be said that the perception of occupational hazards of agricultural workers has changed.

It is an important process to take steps to avoid possible risks, to identify potential hazards and analyse risks, and to evaluate the measures to be taken by making risk assessments. With the harmonious work between the business owners or employer, occupational health and safety specialist, occupational health and safety specialist, workplace physician, other assistant health personnel and other employees, the success in agricultural activities will contribute to occupational safety management (Özkan and Dilay, 2019). Agricultural machinery parking areas should be established in places where agricultural activities are common. Not only will control be ensured within security, but also storage and protection will be easier. On the other hand, outside of seasonal activities, these areas will be protected in closed areas, while their depreciation period and service life will increase. Maintenance or repair expenses will be carried out by the service or technical staff to be kept in these places. In addition, the use of common machinery will enable more work and utilization from one machine. While creating a planning consciousness of the farmers in the region, it will stimulate the instinct of unity and solidarity among the communities in this region, and will facilitate the behavior of acting together. It is important for each enterprise to reveal its own occupational safety risk analysis according to the activities and characteristics of the enterprises. The authority and responsibility for the implementation of risk analysis and implementation in enterprises comes primarily from business managers and employers. Employees in these activities should make maximum effort and effort to fulfil these practices and responsibilities. As a result; it should not be forgotten that most work accidents that occur in agricultural enterprises can be avoided and can be prevented with simple measures. In enterprises with agricultural lands, the level of knowledge, personal protective measures and attitudes of people with high perceptions about the measures to be taken against accidents and high-income levels increase.

REFERENCE

Akbolat, D. (2007). Work Safety. SDU. Faculty of Agriculture, Department of Agricultural Machinery. (Unpublished lecture notes).

Alçayır, A. (2018). Determination of Occupational Accidents Caused by Tractors and Agricultural Machinery in Konya Province umra District Agricultural Enterprises. Master's Thesis. Selcuk University. Institute of Science. Konya.

Anonymous, (2022). Person Under Tractor Died in Konya. Retrieved from https://www.karamanhabercisi.com/konyada-traktorun-altinda-kalan-kisi-oldu-45449h.htm on November 10, 2024.

Güğerçin, Ö and Baytorun, A.N. (2018). Occupational Accidents in Agriculture and Necessary Measures. Çukurova Journal of Agricultural Food Sciences, 33(2), 157-168.

Özay, S. (2022). Occupational health and safety risks in agriculture are very diverse. Retrieved from http://www.turktarim.gov.tr/Haber/788/tarimda-is-sagligi-ve-guvenligi-riskleri-cok-cesitli on November 13, 2024.

Özkan, A and Dilay, Y. (2019). Risks in Agricultural Sector. Journal of Multidisciplinary Engineering Science Studies (JMESS) 5 (12), 2953-2955.

Özkan, A., & Dilay, Y. (2020). Evaluation of Tractor and Agricultural Machinery Accidents in Agricultural Production in Karaman Province. Journal of Agricultural Machinery Science, 16(1), 32-39.

Peker, A. and A. Özkan, (1994). Evaluation of tractor and agricultural machinery accidents in Karaman region between 1973-1993. *Paper presented to the 15th National Congress on Agricultural Mechanization.*

Tiwari, P. S., Gite, L.P., Dubey, A.K. and Kot, L.S. (2002). Agricultural Injuries in Central India:Nature, Magnitude, and Economic Impact. Journal of Agricultural Safety and Health, 8(1), 95-111.

Yıldırım, C., & Altuntaş, E. (2015). Evaluation of occupational accidents caused by the use of tractors and agricultural machinery in Tokat province in terms of occupational safety. Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG),32(1), 77-90.