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From Knowledge to Wisdom

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Batch Studies for Methylene Blue Removal and Recovery by Untreated Coffee Residues

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Abstract: This paper reports the practicability of using coffee residues to remove widely used basic dyes like MB (Methylene Blue) from wastewaters. The effect of different batch system parameters, namely stirring speed, pH, initial dye concentration and contact time were studied. Moreover, in continuous fixed-bed column systems, the effects of parameters such as bed-depth, flow rate and initial dye concentration were examined. The experimental batch systems data were simulated using (a) Freundlich, Langmuir and Sips isotherm models and (b) 1st order, 2nd order, and intra-particle kinetic models. The results revealed that the MB is fairly adsorbed on coffee residues. This process could be a low cost technique for the removal of basic dyes from aqueous systems.

Key words: Adsorption, desorption, column, MB (Methylene Blue), coffee residues, wastewaters.

1. Introduction

Many industries, such as paper, plastics, food, printing, leather, cosmetics and textile, use dyes in order to color their products [1]. In textile industries about 10-15% of the dye gets lost in the effluent during the dyeing processes which are harmful products and may cause cancer epidemics [2]. Dyes usually have a synthetic origin and complex aromatic molecular structures which make them more stable and more difficult to biodegrade [3]. The industrial runoffs are usually discarded into rivers and lakes, altering the biological stability of surrounding ecosystems [4]. Therefore, removal of dyestuffs from wastewater has received considerable attention over the past decades [5].

In wastewater treatment, various methods applied to remove dyes include photocatalytic degradation [6], membrane separation, chemical oxidations [7] and electrochemical process. Among the above mentioned techniques of dye removal, the process of adsorption gives the best results as it can be used to remove different types of coloring materials [8].

Adsorption onto activated carbon is the most widespread technology for the removal of pollutants from water and wastewaters. The disadvantage of activated carbon is its high cost [9]. Hence, it is of pivotal importance thence of low-cost substitute absorbents to replace activated carbons. Various types of untreated biomass have been reported to have a use in dye removal: peanut husk, palm kernel fibre [10], *Turbinaria turbinate* alga, graphene, defatted jojoba and sugar beet pulp [11]. The sorption efficiency of several adsorbents is presented in Table 1.

Further, numerous pretreated lignocellulosic materials are used to remove dyes in water and wastewater. Pyrolyzed date pits, date stones and *Turbinaria turbinate* alga have proved to be effective adsorbents.

2. Materials

Coffee residues and others similar byproducts like coffee husks and coffee grounds have been investigated to remove various dyes and heavy metals from aqueous solutions. Coffee husks have been used for the removal of Cu (II), Cr (VI), Cd (II) and Zn (II),

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coffee grounds for Nylosan Red N-2RBL and degreased coffee bean for Malachite Green. It is reported that the removal of Remazol Brilliant Blue RN and Basic Blue 3G is using coffee residues, focusing on batch processes and not on continuous systems [12].

In the current study, the adsorption capacities of coffee residues to remove MB (Methylene Blue) from aqueous solutions were investigated. Both batch and continuous fixed-bed-column systems were investigated. As regards the fixed-bed-column systems filed with coffee residues, various bed-depths, flow rates and initial dye concentrations were examined for the first time.

3. Methods

Coffee residues, a low-cost material acquired from different cafeterias in the city of Piraeus (Greece) were used as adsorbent. This adsorbent was washed with distilled water and dried at 110 °C for 24 hrs to remove the humidity.

The dye used herein in batch and column experiments was MB ($C_{16}H_{18}ClN_3S{\cdot}3H_2O$, molecular weight = 373.90 × 10^{-3} kg·mol^{-1}) supplied by Sigma-Aldrich. A stock solution was prepared by dissolving a specific amount of MB (humidity 22%) in distilled water. Working solutions were 3-140 mg·L^{-1}. MB concentrations were determined by measuring the absorbent values in each experiment with HACH DR4000U UV-VIS spectrophotometer at λ = 664 nm.

Isotherms were obtained from batch experiments. Accurately weighted quantities of approximately 0.5 g coffee residues were transferred to 0.8 L bottles, where 0.5 L adsorbate solution were added. The temperature was 23 °C, the MB initial concentration ranged from C_0 = 1.5 mg·L^{-1} to 150 mg·L^{-1}. The bottles are sealed and mechanically agitated for a period of 7 days. The 7-day period was determined after optimization analysis, with agitation periods varying from 4 hrs to 14 days, to ensure that nearly equilibrium conditions were achieved. The final concentrations were determined. Concentrations (before and after equilibrium) from each bottle represented one point on the adsorption isotherm plots. The pH was near 7.5.

Batch experiments were carried out at stirring speeds from 65 to 664 rpm, pH varied from 1.54 to 12.9, the adsorption temperature varied from 23 to 70 °C, initial dye concentration from 3 to 140 mg·L^{-1} for a maximum contact time up to 95 min. Samples were taken at 5 minutes intervals and the MB concentration was measured. The reactor, containing V = 1 L aqueous solution of dye was placed in a water bath to maintain constant temperature at the desired level.

The study of the coffee residues by SEM (Scanning Electron Microscopy) was conducted at the Institute of Materials Science, National Centre for Scientific Research ‘Demokritos’, using an FEI Inspect SEM.

The concentration of output solution was measurement at λ = 664 nm and using HACH DR4000U UV-vis spectrophotometer. Finally, pH measurements were made using a digital pH meter, Multi Lab model 540.

4. Results

The SEM micrographs for coffee residues before and after MB adsorption are presented in Fig. 1. The coffee residues particle in Fig. 1(a) with magnification 7,500X shows some pores. The surface texture of this particle is relatively rough as it can be observed in Fig 1(b) with magnification 30,000X. The adsorption conditions were C_0 = 140 mg·L^{-1}, t = 95 min, m/V = 1 g·L^{-1}, agitation speed = 664 rpm. The texture of the coffee residues particles after MB adsorption in Fig. 1(d) is rougher comparing to the same material before MB adsorption, presented in Fig. 1(b). This fact indicates the swelling effect on the lignocellulosic particles after MB adsorption.

Three isotherm models including Freundlich (1906), Langmuir (1916) and Sips (1948) [13] equations were

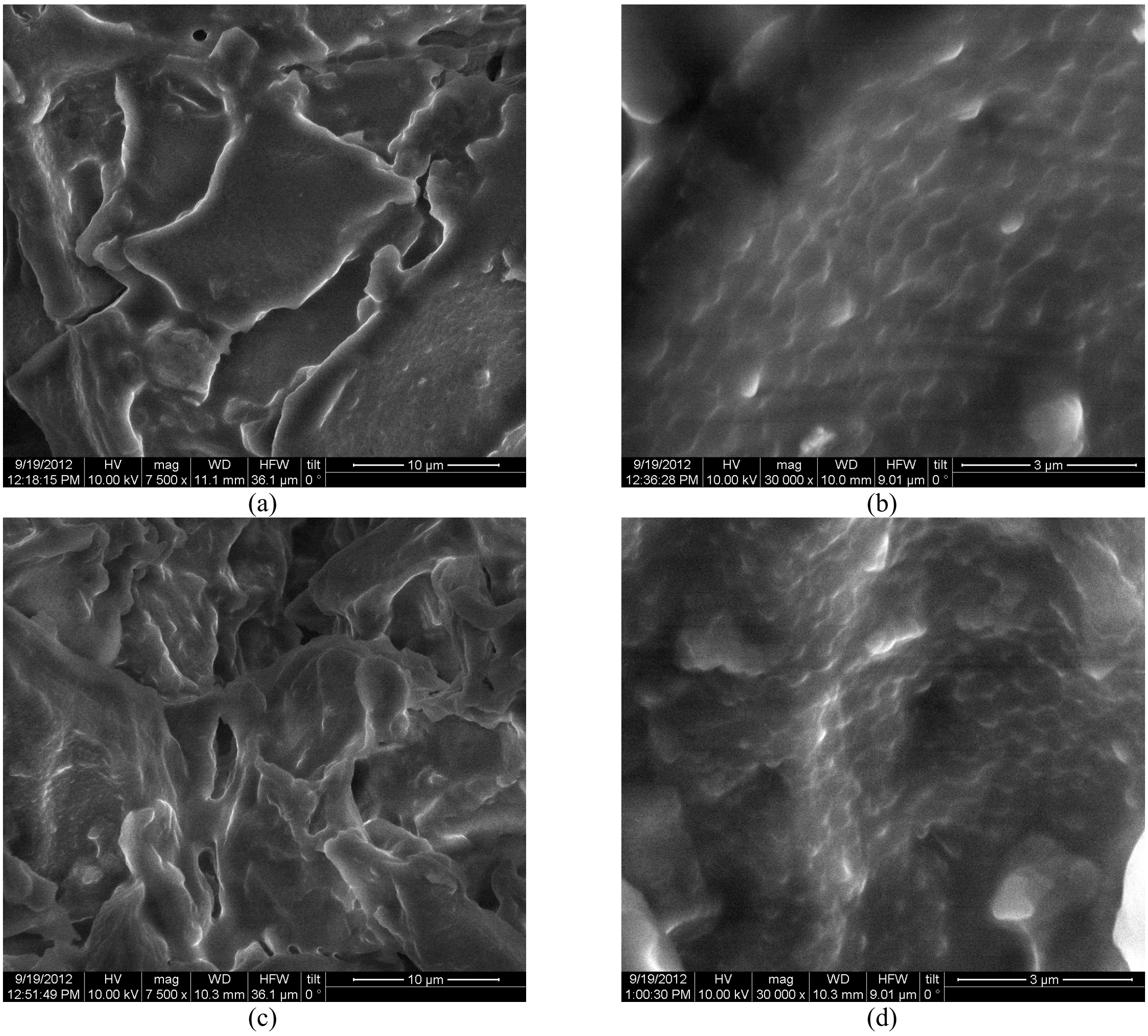

Fig. 1 SEM analysis for coffee residues.

used to fit the experimental data. Freundlich isotherm model assumes that the surface of absorbent is where heterogeneous and polymolecular layer adsorption takes place. This model can be described byEq. (1):

$$q = K_F \cdot (C_e)^{\frac{1}{n}} \tag{1}$$

where q is the amount adsorbed per unit mass of the adsorbent (mg·g^{-1}), C_e is the equilibrium concentration of MB adsorbed (mg·L^{-1}), K_F [(mg·g^{-1})(L·mg^{-1})$^{1/n}$] is the Freundlich isotherm constant related to adsorption capacity and n is the Freundlich isotherm constants related to adsorption intensity. In cases where the isotherm experimental data approximates the Freundlich equation, the parameters K_F and n can be estimated either by plotting log$q$ versus logC_e either by NLRA (Non-Linear Regression Analysis). The linear form of the Freundlich isotherm model can be defined by Eq. (2):

$$\log q = \log K_F + \frac{1}{n}\log C_e \tag{2}$$

The Langmuir (1916) isotherm model is given as:

$$q = \frac{K_L q_m C_e}{1 + K_L C_e} \tag{3}$$

Moreover, this equation in linearized form is:

$$\frac{1}{q} = \left(\frac{1}{q_m}\right) + \left(\frac{1}{K_L \cdot q_m}\right) \cdot \left(\frac{1}{C_e}\right) \tag{4}$$

where K_L is the Langmuir constant related to the energy of adsorption (L·mg^{-1}) and q_m is the amount of MB adsorbed ($mg \cdot g^{-1}$) when saturation is attained. In cases where the isotherm experimental data approximates the Langmuir equation, the parameters K_L and q_m can be estimated either by plotting $1/q$ versus $1/C_e$ either by NLRA.

Numerous studies incorporate another important parameter, R_L, namely the separation factor. The value of R_L indicates the type of the isotherm to be either unfavorable ($R_L > 1$), linear ($R_L = 1$), favorable ($0 < R_L < 1$) or irreversible ($R_L = 0$) and is expressed by Eq. (5):

$$R_L = \frac{1}{1 + K_L \cdot C_0} \quad (5)$$

where C_0 is the initial dye concentration ($mg \cdot L^{-1}$) and K_L is the Langmuir constant ($L \cdot mg^{-1}$).

Sips (1948) [13] isotherm model is a combination of the Langmuir and Freundlich isotherm type models and is expected to describe heterogeneous surface better. The Sips equation is presented by Eq. (6):

$$q = \frac{q_m \cdot (K_L \cdot C_e)^{1/n}}{1 + (K_L \cdot C_e)^{1/n}} \quad (6)$$

where K_L ($L \cdot mg^{-1}$), q_m ($mg \cdot g^{-1}$)is the Langmuir constants and n the Freundlich constant. These parameters can be estimated by NLRA.

MB adsorption isotherms experimental data for untreated coffee residues are presented in Fig. 2. The theoretical curves are estimated for the above mentioned three models. The parameter values of these models are shown in Table 1. These parameters were obtained by NLRA. The SEE (Standard Error of Estimate) was calculated in each case as Eq. (7):

$$SEE = \sqrt{\sum_{i=1}^{n'} (y_i - y_{i,theor})^2 / (n' - p')} \quad (7)$$

where y_i is the experimental value of the depended variable, $y_{i,theor}$ is the theoretical or estimated value of the depended variable, n' is the number of the experimental measurements and p' is the number of parameters (the difference $n - p'$ being the number of the degrees of freedom.

The fitting of the Sips adsorption model to the present data was the most satisfactory for MB adsorption, better than the other two isotherm models, as shown by the corresponding SEE-values given in Table 1. The fitting of the Langmuir's adsorption model to the present data was also satisfactory but to a lesser degree than the Sips model. The R_L values were found to be 0.236-0.935, i.e. $0 < R_L < 1$ for all MB concentrations C_0 in the range of 3-140 $mg \cdot L^{-1}$.

In order to make adsorption mechanism more clear, the adsorption data were fitted using the pseudo-first order, the pseudo-second order and the intra-particle diffusion kinetic model.

The Lagergren (1898) [12] non-linear pseudo-first order equation is given as Eq. (8):

$$q - q_t = q \cdot e^{-k \cdot t} \quad (8)$$

where q and q_t ($mg \cdot g^{-1}$) are the amounts of MB dye adsorbed per unit mass of the adsorbent at equilibrium time ($t \to \infty$) and adsorption time t (min), respectively, while k (min^{-1}) is the pseudo-first order rate constant for the adsorption process. Moreover:

$$q = (C_0 - C_e)V / m \text{ and } q_t = (C_0 - C)V / m \quad (9)$$

where C, C_0 and C_e ($mg \cdot L^{-1}$) are the concentrations of MB in the bulk solution at time t, 0 and ∞, respectively, while m (g) is the weight of the adsorbent used, and V (mL) is the solution volume. Further modification of Eq. (9) in logarithmic form gives:

Table 1 Isotherms' parameters of Methylene Blue dsorption on coffee residues.

	K_F[($mg \cdot g^{-1}$)($L \cdot mg^{-1}$)$^{1/n}$]	n	K_L ($L \cdot mg^{-1}$)	q_m ($mg \cdot g^{-1}$)	SEE
Freundlich	3.555	1.612			2.397
Langmuir			0.0230	78.90	2.197
Sips		1.195	0.0111	109.27	2.168

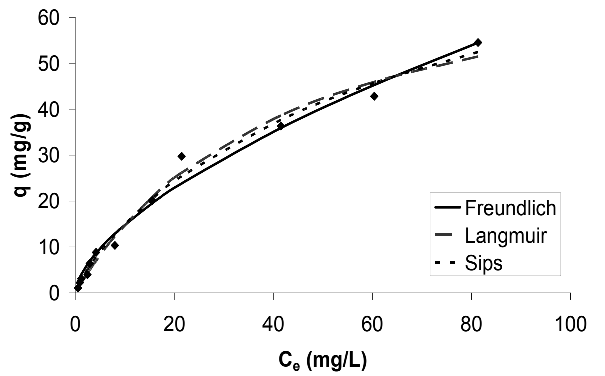

Fig. 2 Isotherm's parameters of adsorption of coffee residues.

$$ln(q-q_t)=lnq-k\cdot t \quad (10)$$

The pseudo-second order equilibrium adsorption model equation is given as Eq. (11):

$$q_t = q-\left[q^{-1}+k_2 t\right]^{-1} \text{ or } q_t = q-\frac{1}{\frac{1}{q}+k_2 t} \quad (11)$$

where k_2 (min^{-1}) is the rate constant of second order adsorption.

The intra-particle diffusion model based on the theory proposed by Weber and Morris (1963) [9] is expressed as Eq. (12):

$$q_t = c+k_p\cdot\sqrt{t} \quad (12)$$

where k_p [mg ($g\cdot min^{0.5}$)$^{-1}$] is the intra-particle diffusion rate constant and c ($mg\cdot g^{-1}$)is a constant related to the thickness of boundary. A value of c close to zero indicates that diffusion is the only controlling step of the adsorption process.

The stirring speed was studied between 65 and 664 rpm at constant dye concentration 14 $mg\cdot L^{-1}$, pH equals 7 and stirring time of 95 min. The correlation between the first-order rate constant k for the MB absorption by coffee residues is shown in Fig. 3. The rate constant is generally increasing with stirring speed up to 200 rpm were a level-off is reached.

According to the literature, the pH of the aqueous solution is one of the most important parameters of the adsorption process. The effect of the initial pH on the MB adsorption onto coffee residues is illustrated in Fig. 4. The range of pH studied was from 2 to 12. As can be seen the rate constant increases linearly by pH increasing.

The effect of initial MB concentration on adsorption on coffee residues is shown in Fig. 5. The kinetic parameters of the above mentioned three kinetic models were estimated using NLRA and are presented in Table 2. As can be seen, the SEE values are lower for the intra-particle diffusion kinetic model indicating better fitting to the experimental data. In addition the pseudo-second order kinetic model had better fitting that the pseudo-first one.

The temperature variation from 20 °C to 70 °C on MB uptake by coffee residues revealed that increase in temperature of the process enhanced better adsorption of MB from bulk solution. The conditions under which they became the experiments with different temperature were pH = 8, the initial concentration was 14 $mg\cdot L^{-1}$,

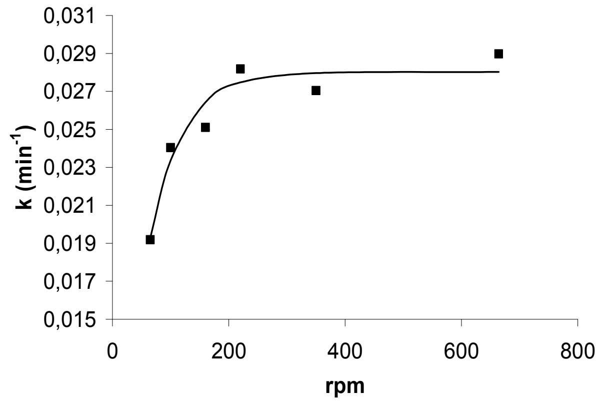

Fig. 3 Effect of stirring speed.

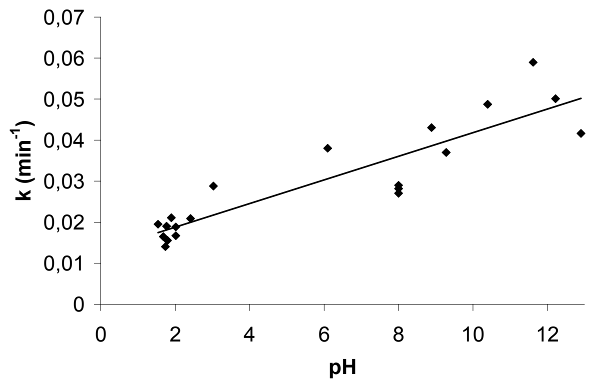

Fig. 4 Effect of pH.

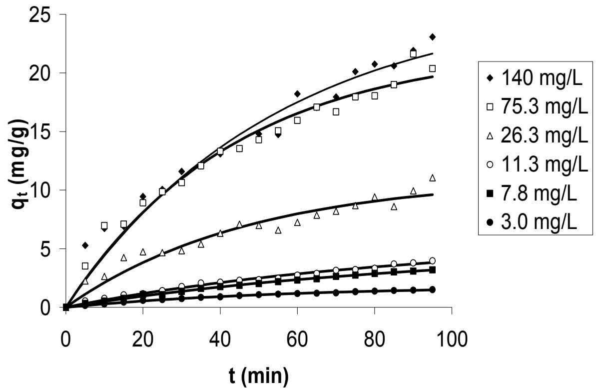

Fig. 5 Effect of initial MB concentration.

the stirring speed was 600 rpm and the dose of coffee residues was 1 g. Increase in temperature increased entropy of the system which yielded more chances of adsorption. The change in adsorption rate constant k as a function of adsorption temperatures is presented in Fig. 6.

The rate constant k of the Lagergren model follows the Arrhenius law:

$$k = p \cdot exp(-E / RT) \quad (13)$$

The activation energy E (kJ·mol^{-1}) for the adsorption of MB on untreated coffee residues can be estimated by linear regression of *lnk* on *1/T*. This activation energy was found to be 27.4 kJ·mol^{-1} or 6.57 kcal·mol^{-1}. The frequency factor of Eq. (13) was p = 1,236 min^{-1}. Consequently, the intra-particle diffusion, which is a physical process, is probably the controlling step of the adsorption process. The parameters of fixed—bed column systems for coffee residues are shown in Table 3.

This study is a research on the adsorption capacity of the coffee residue and its application to industrial scale. There is object for further research to determine the coffee residues quantity by region distribution and corresponding exploitation by industrial scale unit.

The MB adsorption capacity for various lignocellulosic materials found in the literature was compared to the coffee residues adsorption capacity estimated in the present work (Table 4). The adsorption capacity of the coffee residue was better than the adsorption capacity of other waste biomass such as peanut husk, *turbinaria turbinate alga*, and wheat straw. The adsorption capacities of various coffee residues/byproducts found in the literature are shown in Table 5. The coffee residues adsorption capacity found in the present work was close to the average of the Freundlich and Langmuir capacities, i.e., K_F and q_m respectively, reported in the literature.

The present study is a part of continues involvement of our Research Group in the study of wastewater treatment using original and modified (pretreated) lignocellulosic biomass as potential adsorbents. Previous study of our Group gave Langmuir capacity q_m = 38.7 mg·g^{-1} for pine sawdust, significantly lower comparing to q_m = 78.9 mg·g^{-1} for the coffee residues studied in the present work.

Table 2 Kinetic parameters of Methylene Blue adsorption on coffee residues.

C_0 (mg·L^{-1})	140	75.3	26.3	11.3	7.8	3.0
First order						
k	0.0183	0.0227	0.0211	0.0113	0.0107	0.0176
q_e	28.78	22.26	11.11	5.79	4.98	1.82
SEE	1.2827	0.9917	0.7150	0.1271	0.0515	0.0243
Second order						
K_2	0.000376	0.000604	0.001139	0.000796	0.000823	0.004587
q_e	37.81	30.99	15.42	9.27	8.18	2.74
SEE	1.1818	0.8594	0.6563	0.1198	0.0488	0.0209
Intra-particle diffusion						
c	-1.05	-0.70	-0.29	-0.49	-0.49	-0.16
k_p	2.3371	2.1586	1.0365	0.4275	0.3647	0.1706
SEE	0.9196	0.6165	0.5137	0.1945	0.1613	0.0535

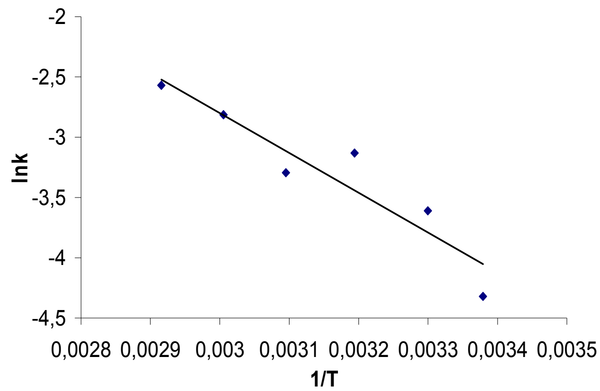

Fig. 6 Effect of temperature.

Table 3 Column models parameters of Methylene Blue adsorption on coffee residues.

	C_i (mg/L)	Q (mL/min)	*n*	N (mg/L)	K	Q_0 (mg/g)	SEE
x = 15cm							
Bohart-Adams	165	20	2.000	42,798	0.000080	96.90	2.3110
Clark	165	20	1.612	40,522	0.000060	91.76	2.3053
Bohart-Adams	130	40	2.000	29,317	0.001400	66.39	0.4876
Clark	130	40	1.612	26,317	0.000100	59059	0.6402
Bohart-Adams	150	70	2.000	31,482	0.000250	71.29	5.8235
Clark	150	70	1.612	28,382	0.000220	64.27	5.1515
Bohart-Adams	145	80	2.000	24,745	0.000210	56.03	7.5229
Clark	145	80	1.612	20,673	0.000180	46.80	6.3513
Bohart-Adams	800	20	2.000	46,166	0.000020	104.54	38.2861
Clark	800	20	1.612	33,869	0.000010	76.69	32.5900
Bohart-Adams	1,600	10	2.000	30,224	0.000010	68.44	102.8607
Clark	1,600	10	1.612	22,024	0.000010	49.87	93.8242
Bohart-Adams	1,600	20	2.000	36,641	0.000020	82.97	103.0998
Clark	1,600	20	1.612	25,017	0.000020	56.64	903.4492
x = 25 cm							
Bohart-Adams	150	70	2.000	38,290	0.000160	86.65	4.0545
Clark	150	70	1.612	35,501	0.000130	80.34	3.7795
Bohart-Adams	800	20	2.000	21,788	2.25E-05	49.30	62.5900
Clark	800	20	1.612	16,007	1.98E-05	36.20	56.0000
Bohart-Adams	550	40	2.000	32,847	8.61E-05	74.30	17.6150
Clark	550	40	1.612	30,028	7.51E-05	68.00	14.6410

Table 4 Methylene Blue adsorption capacity for various lignocellulosic materials.

Adsorbents	Pretreatment	$K_F[(mg\cdot g^{-1})(L\cdot mg^{-1})^{1/n}$	*n*	$q_m(mg\cdot g^{-1})$	$K_L(L\cdot mg^{-1})$
Activated carbon fibers	Chenmical vapor deposition modified	120.000	1.460	478.00	0.3750
Cocoa	carbonized, burn	40.850	8.090	212.77	0.2690
(The *obroma cacoa*) shell	activated				
Coffee residues	-	3.555	1.612	78.90	0.0230
Commercial activated carbon		-	-	370.40	1.0500
Cotton stalk	-	50.440	6.150	147.06	0.0249
Cotton stalk	sulfuric acid treated	202.210	1.810	555.56	0.6207

Table 4 continued

Adsorbents	Pretreatment	K_F[(mg·g^{-1})(L·mg^{-1})$^{1/n}$]	n	q_m(mg·g^{-1})	K_L(L·mg^{-1})
Cotton stalk	phosphoric acid treated	157.910	16.150	222.22	14.516
Date pits activated carbon	Pyrolyzed, $FeCl_3$ activated	74.871	4.670	249.46	0.0830
Date stones activated carbon	Pyrolyzed, $ZnCl_2$ activated	71.190	3.440	369.38	0.0429
Enteromorph a prolifera activated carbon	$ZnCl_2$ activated	236.230	3.720	270.27	1.2300
Graphene	-	90.920	5.710	153.85	1.4400
Jojoba (defatted)	-	1.132	1.054	167.00	0.0009
Palm kernel fiber	-	8.670	1.770	95.40	0.0317
Peanut husk	-	16.650	3.270	72.13	0.0850
Pine sawdust	Autohydrolyzed	15.680	2.582	88.02	0.1072
Pistachio hull	-	112.300	4.200	389.00	0.0960
Posidonia oceanic (*L.*) dead leaves activated carbon	Carbonized, $ZnCl_2$ activated	112.120	2.740	217.390	1.7000
Sugar beet pulp	-	12.520	1.990	244.600	0.0149
Sugar beet pulp	-	2.777	10.128	714.290	0.0039
Tea (rejected)	NaOH modified	40.870	2.110	242.110	0.1300
Turbinaria turbinaria alga	-	14.000	2.310	63.000	0.1830
Turbinaria turbinaria alga	pyrolyzed	40.000	3.030	163.000	0.1040
Turbinaria turbinaria alga	pyrolyzed, physically activated	105.000	3.630	411.000	0.0830
Turbinaria turbinaria alga	pyrolyzed, chemically activated	137.000	5.670	345.000	0.136
Wheat straw	Acid hydrolyzed	10.950	1.010	20.410	0.663

Table 5 Adsorption capacity of various coffee residues/byproducts.

Adsorbents	Adsorbates	K_F[(mg·g^{-1})(L·mg^{-1})$^{1/n}$]	n	q_m(mg·g^{-1})	K_L(L·mg^{-1})
Coffee grounds chemically activated carbon	Nylosan Red N-2RBL	-	-	367	0.077
Coffee grounds chemically activated carbon	Methylene blue	-	-	181.8	0.109
Coffee husk-based activated carbon	Remazol brilliant Orange 3R dye	3.747	3.608	66.76	0.401
Coffee husks	Methylene blue	2.567	1.29	90.09	0.0226
Coffee grounds	Methylene blue	51.926	3.30	18.73	0.2687
Coffee bean (degreased)	Methylene green	2.03	0.511	55.3	0.0935
Coffee residues	Remazol brilliant Blue RN	11.84	2.53	175	0.009
Coffee residues	Basic Blue 3G	36.61	3.12	240	00.041
Coffee husks	Cu(II)	3.702	5.01	7.496	0.4232
Coffee husks	Cd(II)	3.188	5.05	6.854	0.3124
Coffee husks	Zn(II)	2.721	6.07	5.565	0.2238
Coffee husks	Cr(II)	2.353	3.65	6.961	0.1805
Coffee residues	Methylene blue	3.555	1.612	78.90	0.0230

5. Conclusions

The use of coffee residues is an innovative technique using waste biomass from urban and rural areas in and Industrial Ecology framework. Also, that is an index of the sensitivity of citizens for the rational management of waste and their contribution to sustainable development. The present work proves the viability of using coffee residues to remove basic dyes like MB from wastewaters. The effect of different system parameters on (a) batch and (b) continuous fixed-bed column systems were studied. The experimental systems data were simulated using the most commonly used isotherm and kinetic models. The continuous fixed-bed column results proved that the MB is practically adsorbed on coffee residues giving maximum Bohart and Adams capacity N = 46,166 mg·L^{-1} or q_0 = 104.5 mg·g^{-1} for bed-depth 15 cm, initial dye concentration 800 mg·L^{-1} and flow rate 20 mL·min^{-1}. These results provide evidence for suggesting this low cost residue for the removal of basic dyes in industrial scale applications.

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The Compatibility Effects of Biochar-Vermicompost Mixes on Crop Productivity

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Abstract: This study sought to establish the compatibility effects of biochar/vermin-compost application on growth and yield of maize and cabbages. Biochar application rate was at 3 to 4% of soil weight. Biochar was mixed in various proportions to come up with treatments which were 100% vermicompost, 50/50% biochar: vermicompost, 75/25% biochar: vermicompost and 100% biochar. The experiment was repeated twice and arranged as a completely randomized design and replicated five times. The study established that maize yield increased with application of biochar from 25% to 50%. In the cabbage trial, comparable results in plant height, leaf numbers and final yield was obtained with 100% vermicompost application, 50% and 75% biochar inclusion. When biochar was applied at 100%, noticeable reduction in plant performance was noted. It is recommended to use biochar as a bio-fertiliser at 50/50% biochar: vermicompost in maize and cabbage production.

Key words: Biochar, vermicompost, crop productivity, compatibility.

1. Introduction

In most arid and semi-arid regions, large areas of cultivated soils are characterised by high sand and low organic matter contents which in turn negatively affects soil physico-chemical properties [1]. These problems are particularly intense in developing countries like Zimbabwe where more than 80% of the population of smallholder farmers still rely on traditional technologies and tools; mainly hand-held hoes, minimal use of animal traction and no tractors [2]. However, soil health is the foundation of vigorous and sustainable crop production. This is characteristic of the semi-arid tropics like Zimbabwe. As a potential solution, the use of biochar as a soil amendment has been introduced.

Biochar is a carbon rich material produced by different thermo-chemical biomass conversion process like pyrolysis. Pyrolysis is a dry carbonization technique typically operated at 400-800 °C [3]. The application of biochar to the soil has been shown to enhance the capacity of the soil to retain nutrients and lessen leaching [4]. Studies done by Githinji, L. [5] have revealed that addition of biochar increases soil porosity and aggregation. Biederman, L. and Harpole, W. S. [6] reported that biochar addition to the soil leads to increased above ground productivity, crop yield, soil microbial biomass, rhizobia nodulation, plant potassium concentration and total soil nitrogen. Jeffery, S., et al. [7] found a 10% increase in the mean yield of various crops. The percentage increases found in literature tends to differ and depends on various factors such as initial soil properties and biochar characteristics [8]. High applications of biochar have been reported to reduce yields [9].

A study by Carter, S., et al. [10] reported increases in above ground biomass after biochar additions to non fertilized soils. However, other studies have found

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that biochar increases the persistence of simazine herbicide. Despite the promotion of biochar as a soil amendment, its compatibility with other soil amendments such as vermicompost is currently unknown. Vermicompost is one of the soil organic amendments that has found its way into Zimbabwean fields and gardens and now that biochar is coming in, the compatibility of these amendments need determination. The study explored the effects of various biochar vermicompost mixes on the productivity of cabbage and maize in a pot trial.

2. Materials and Methods

2.1 Experimental Site

Two experiments were carried out at BUSE (Bindura University of Science Education) nursery and were repeated twice. BUSE is located at the coordinates: 17°18'58'' S and 31°19'23'' E. The two sites are located in agro-ecological region 11a of Zimbabwe [11] and receive about 800 mm rainfall per annum. The average temperature for both areas was 25 °C. The soil used at both sites was medium grained sands with a pH of 4.1 ($CaCl_2$).

2.2 Experimental Details

Biochar used in the experiments were obtained from the pyrolysis of maize stova. Biochar/vermicompost mixes used in these experiments were in the proportions 50/50, 75/25 vermicompost/biochar and 100% biochar. The mixes were used to fill the pots. Maize fert (7% N, 14 P, 7 K) was applied at a rate of 300 Kg/ha. At topdressing, 5 grammes of ammonium nitrate (35.5%) was applied at a rate equivalent to 250 kg/ha. The experiment was arranged as a completely randomized design with five replications. The experiment was repeated twice over time. Watering was done at 50% moisture depletion calculated using the evaporation pan measurements relevant at each crop stage. For tomatoes the weekly fungicide sprays were done through alternating copper oxychloride and Dithane M45.

2.3 Data Collection and Analysis

The data from the two repeats of the same experiment were pooled together prior to analysis. The data was analysed according to the model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where μ is the average mean, T_i means the treatment effects and e_{ij} is the error term.

Data on plant growth parameters were subjected to analysis of variance using Genstat Version 13. The least significant test (LSD (Least Significance Difference) 0.05) was used to separate treatment means of the measured parameters with significant differences.

3. Results and Discussion

3.1 Maize Leaf Number

The results indicate that biochar inclusion at 50% performed similarly to vermicompost but was significantly ($p < 0.05$) higher compared to inclusion at 25% (Fig. 1).

3.2 Maize Yield

The same trend was observed on maize yield with biochar inclusion at 50% having the highest yield compared to the rest of the treatments (Fig. 2).

3.3 Cabbage Height

There was no significant variation in cabbage plant height when biochar is applied at 50% and 75% when compared to vermicompost alone ($p > 0.05$). The application of biochar in cabbage production at 100% resulted in significantly reduced plant height ($p < 0.05$) when compared with application of vermicompost alone or biochar at 50% and 75% (Fig. 3).

3.4 Cabbage Leaf Canopy

The cabbage leaf canopy diameter was similar at 50% and 75% biochar inclusion when compared with 100% vermicompost application ($p > 0.05$). However, at 100% biochar application rate, there was a significant

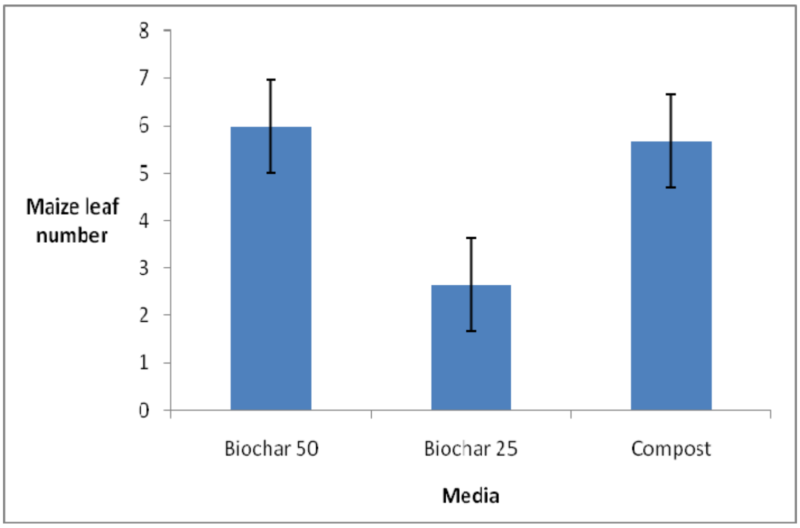

Fig. 1 Effect of various biochar/vermicompost mixes on maize leaf number.

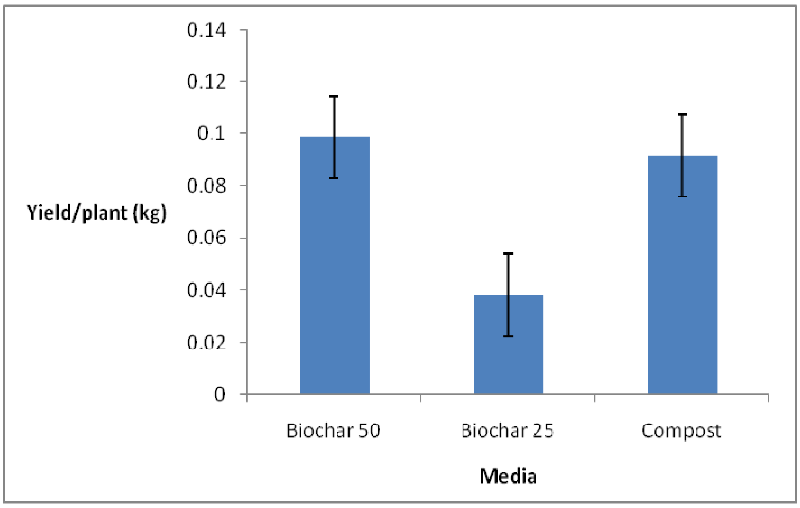

Fig. 2 Effect of biochar vermicompost mixes on maize yield.

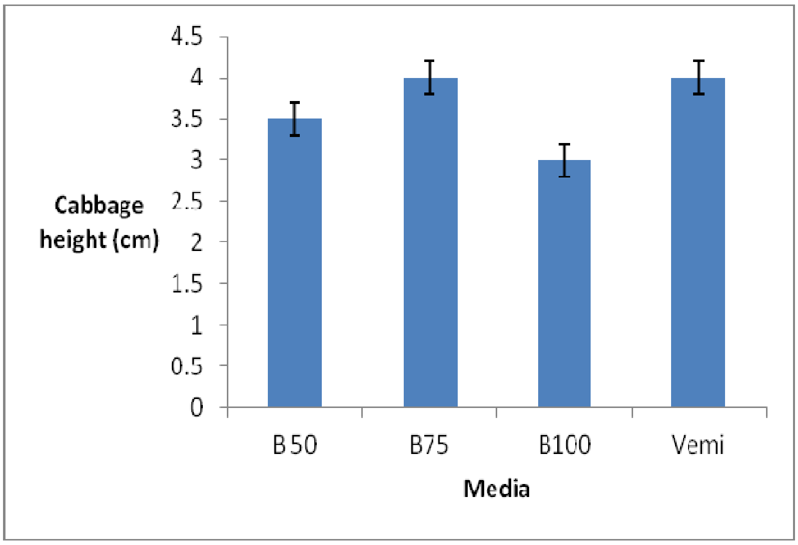

Fig. 3 Effect of biochar vermicompost mixes on Cabbage plant height.

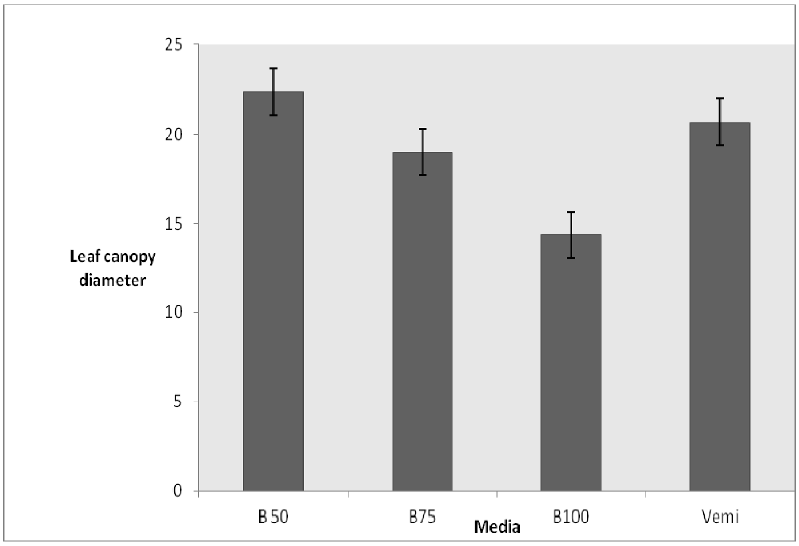

Fig. 4 Effect of biochar/vermicompost mixes on cabbage leaf canopy.

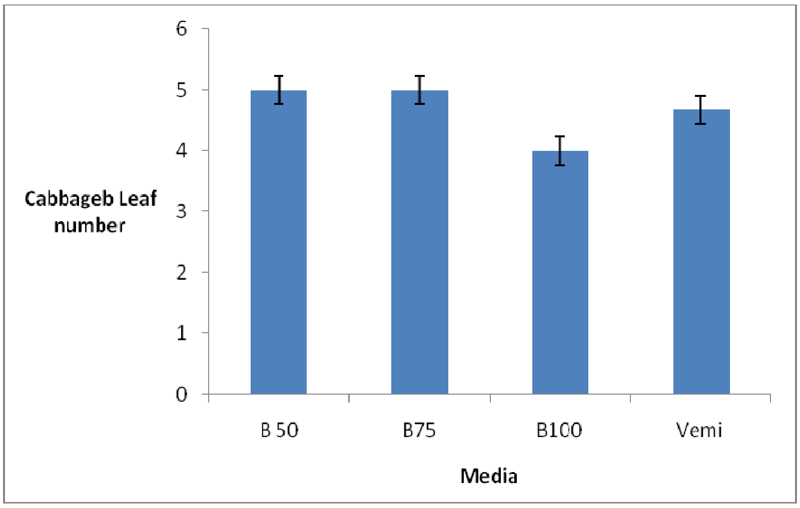

Fig. 5 Effects of biochar/vermicompost mixes on cabbage leaf number.

reduction in the cabbage leaf canopy ($p < 0.05$) (Fig. 4)

3.5 Cabbage Leaf Number

There was no significant difference in cabbage leaf numbers grown under vermicompost alone compared to 50% and 75% biochar application rate ($p > 0.05$). A significant reduction in the number of cabbage leaves was noted when biochar was applied at 100% compared to vermicompost only and biochar application at 50% and 75% ($p < 0.05$) (Fig. 5).

4. Discussions

The study focused at establishing the effect of Biochar/Vermin-compost application on growth and yield of maize and cabbages. Maize yield increased with increasing application of biochar from 25% up to 50%. This is in tandem with the results of other researches from elsewhere in the world [12, 13]. The noticeable higher performance in maize with increased biochar application could be attributed to the improved soil physico-chemical characteristics of the soil which include among other properties the capacity of the soil to retain nutrients, increased cation exchange capacity and lessened leaching. Vermicompost could be the supplier of the nutrients while biochar preserves them for crop usage. The results also serve to confirm the compatibility of the two organic soil amendments on crop productions. The usage of the mixes may be limited to the 50% inclusion level as any further increase in biochar did not yield a proportional benefit.

This agrees with Yamato, M., et al. [14] who indicated that the mobile portion consists of biochar short-term effects, the resident portion carries its long-term effects which vary with concentration levels. Within the mobile portion, the organic part acts much like other degradable carbon sources (e.g. compost or detritus). It contains dissolved organic carbon and organic matter that is available to soil microbes. The availability of the organic matter for plant growth will depend on the quantities applied to the soil.

In the cabbages, there was a similar response in all parameters measured to vermicompost/biochar application, comparable results in plant height, leaf numbers and final yield were obtained with 100% vermicompost application, 50% and 75% biochar inclusion. When biochar was applied at 100%, noticeable reduction in plant performance was noted. This agrees with Verhejien, F., et al. [15] and Lehmann, J., et al. [16] who established that biochar helps in nutrient retention and cannot work on its own in nutrient supply. Biochar works in combination with other soil components such as soil microbes to improve the overall soil dynamics, the conditions in which plants grow over a long term. This allows for better plant nutrition, improved plant growth and yield and brings overarching benefits to agricultural soil productivity.

This was further confirmed by Vincent, V., Thomas, R. G., Chan, K. Y., Xu, Z. and Julie, M. [11, 17, 18] who noted that, one reason for the ability of Amazonian Terra Preta soils to maintain high fertility, compared to adjacent infertile soils, is their ability to retain nutrients.

Biochar has properties for high cation exchange capacity which allows it to retain positive ions in a form that is exchangeable. These positive ions, vital nutrients such as ammonium or potassium cations, are availed to plants when needed. This is so, because oftentimes when conventional fertilizers are applied to poor soils, the nutrients end up lost through leaching, weeds, or microbial activity before crops utilizes them.

5. Conclusion

It can be concluded from this study that the there are synergistic effects of mixing biochar and vermicompost with a limit of 50% inclusion rate with vermicompost in order to improve maize and cabbage productivity.

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Pleistocene Birds of Gruta da Furninha (Peniche-Portugal): A Paleontological and Paleoenvironmental Aproach

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Abstract: The cave-site of Gruta da Furninha is a coastal karstic cavity. In the late 19th century, excavation of the sedimentary infill of the cave allowed the identification of two lithostratigraphic units: a Holocene one dominated by sands, containing human bones and a Neolithic industry; and a Late Pleistocene one, containing a diverse set of fossils set and Paleolithic artifacts. This study mainly focuses on taphonomic and palaeoenvironmental data concerning the Pleistocene bird bones that were collected from six layers (at 11 m and 6.7 m asl). A main result of this study was the discovery of a left humerus fragment, with osteological features of the Alcidae family; from comparison with upper arms of distinct species of this family, it was concluded that this fossil belongs to *Penguin impennis*. The Pleistocene birds of the Furninha cave were also compared with the avifauna that currently occurs in the region of Peniche peninsula and a climate and environmental interpretation of the Pleistocene fossiliferous set is provided.

Key words: Birds, Pleistocene, marine caves, Portugal.

1. Introduction

The Furninha cave is a coastal karstic cavity in Lower Jurassic limestones, located ca. 850 m SE of Cape Carvoeiro, on the southern coast of the Peniche peninsula (western coast of central mainland Portugal), about 75 km north of Lisbon (39°21’23’’ lat. N and 9°26’14’’ long. W). This cave has an entrance of marine genesis located in the middle part of the coastal cliff, at ca. 15 m asl.

The sedimentary infilling of the cave was excavated in the late 19th century by Delgado, J. F. N. [1], which defined two main stratigraphic units: a Holocene unit and a Pleistocene unit. Later, Breuil, H. and Zbyszewski, G. [2] identified at the base of the lower unit (at 6 m asl) a marine stratigraphic level, which they ascribed to the Riss-Wurm interglacial.

In the upper unit “Entulho Superior” (Upper Rubble), some of the bones collected are human. In the ca. 8 m-thick lower unit “Areias Quaternárias” (Quaternary Sands), with 7 main “níveis ossíferos” (bone-rich levels) I to VII, were recognized, several separated by a travertine and nine of them rich in well-preserved faunal bones [1]. A description of the sedimentary succession, including fossils and artifacts, can also be seen in Ref. [3].

Cunha, P. P., et al. [4] made a detailed characterization of this coastal area. Several wave-cut platforms and associated sedimentary deposits were mapped and located, respectively, at (asl): 33-36 m;

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24-27 m; 20-21 m; 15-17 m; 10-12 m and 6-8 m.

The first vertebrate inventory of fossils collected from the Pleistocene unit listed ca. three dozen mammalian taxa and showed the presence of birds, fish and chelonians [1]. Later, this Late Pleistocene fauna was more thoroughly studied by Harlé, E. [5]. In the case of birds, Harlé benefitted from the collaboration of Newton. Some other publications addressed the fossil remains of Furninha cave [6-8], but all of them just repeated the data already published by Harlé. During the 20th century and early 21st century, the mammals were revisited, and new analyses were provided [9, 10]. In the case of birds, until 2007, the bibliography only reproduced the results of the study made by Newton in Harlé [5]. Since 2008, there have been some new studies (paleontology, taxonomy, taphonomy and paleoenvironment) focused on fossil birds from Furninha cave [9-15].

Until now, the bibliography related to the Furninha cave avifauna had two gaps: (i) the downgrading of taxonomic nomenclature; and (ii) the lack of detailed study of the majority of the bird remains (only 20% of the total was previously studied).

2. Material and Methods

The present study is focused on the analysis of all the bird remains from Gruta da Furninha (436 bones), currently housed at the Geological Museum of LNEG (Laboratório Nacional de Energia e Geologia) in Lisbon. The analyzed avifauna remains of Furninha cave were complemented with literature search and through comparison with the reference osteological collections (Arqueosciences Laboratory of General Direction of Cultural Heritage; Achaeozoology and Paleontology Laboratory of Portuguese Center of Geo-History and Prehistory). The association of taxonomic data with the environment of the species identified, according to the respective stratigraphic level of provenance, was also carried out.

3. Previous Studies

3.1 Geoarchaeology

Delgado, J. F. N. [1] published results in outstanding detail and the archaeological materials have been successively reviewed or acknowledged [2, 3, 5-7, 16-19]. The upper lithostratigraphic unit ("Entulho Superior") encompasses an early to late Neolithic necropolis with abundant organic material, osteological human remains, personal adornments, bone tools and pottery along with polished and knapped stone tools [18] (Table 1).

The lower lithostratigraphic unit Quaternary Sands ("Areias Quaternárias") comprises a sedimentary succession containing artifacts encompassing a sequence between the Middle and Upper Paleolithic, with assemblages pointing to the Acheulian, Mousterian, Gravettian, Solutrean and Magdalenian [3], most of them—especially the Mousterian industries—in association with abundant and diverse faunal remains [1, 5-15] (Tables 1 and 2 and Fig. 1).

Unfortunately, the site has very few absolute dates. Two radiocarbon AMS (Accelerator Mass Spectrometry) dates, one on human bone and another on a bone pin from the upper unit (Holocene) confirm that part, at least, of the necropolis identified from the upper unit dates from the Late Neolithic [18, 20, 21]. Another age,

Table 1 Stone-tool assemblage from Furninha cave, according to Delgado, J. F. N. [1]; Bicho, N. and Cardoso, J. L. [3]; Cardoso, J. L. and Carvalho, A. F. [18].

	Flint	Quartzite	Quartz	Limestone	Amphibole	Other	Total	Reference
Acheulean	1							1
Mousterian	25	2				4	31	3
Gravettian	24					1	25	3
Solutrean	9						9	3
Magdalenian	8						8	3
Indeterminate	46	1					47	3
Neolithic	70	1		1	26	4	102	3

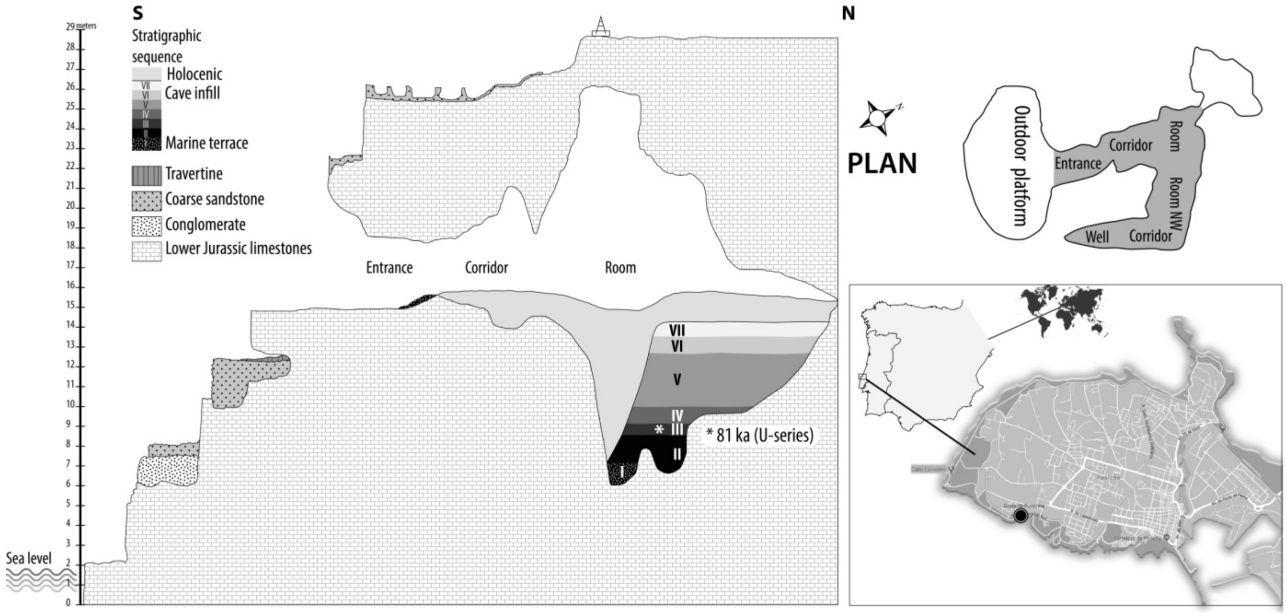

Fig. 1 Stratigraphy, plan and localization of the Furninha cave.

Table 2 Stratigraphic levels of the Pleistocene lithostratigraphic unit and correspondence of the different fauna groups for each of these levels, according to Delgado, J. F. N. [1].

Main subunits	VII		VI	V	IV		III		II			I
Stratigraphic levels (m asl)	1 (13.5)	1 (13)	2 (12.8)	1 (10)	1 (9.2)	1 (9)	2 (8.7)	3 (8.5)	1 (7.2)	2 (7.1)	1 (6)	2 (5.7)
Mammals	*	*	*	*	*	*	*	*	*	*	*	*
Birds		*	*	*		*		*	*		*	*
Reptiles			*	*								
Amphibians				*		*		*				
Invertebrates											*	*
Artifacts	*	*	*		*	*		*	*	*		

resulting from Uranium-series dating of a bone collected from the 3th stratigraphic level (8.5-9 m asl), is 80,880 + 42, 420 – 31, 260 years [22] (Fig. 1), but cannot be used as a reliable chronological marker due to the large standard deviation.

3.2 Paleontology

Previous studies [1, 5-10, 13-15] allowed the identification of the vertebrate taxa of the Furninha cave faunas and their distribution by the various stratigraphic levels (Figs. 1 and 3): carnivorous mammals (*Ursus arctos, Hyaenaprisca, Panthera pardus, Lynx pardina, Canis lupus, Vulpesvulpes, Melesmeles and Martessp*); herbivores (cervids, *Dicerorhinus hemitoechus, Bos primigenius, Equus caballus* and *Sus scrofa*); *Paleoloxodont antiquus*, *Oryctolagus*, flying mammals (order Chiroptera); amphibians; turtles; lizards and birds.

4. Results

4.1 Osteological Data

A total of 436 bones of birds were identified (10% of the total number of vertebrate remains), collected from six of the seven Pleistocene stratigraphic levels of the Furninha Cave (Table 2). Most (95.4%) are bones of the appendicular skeleton. Of these, 36.2% are from hind limbs and 59.2% are from anterior limbs (Fig. 2). Of the remaining bones, 4.3% belong to the axial skeleton and only 0.3% to the cranial skeleton (a skull of *P. graculus*). The remaining variables have opposite signs, indicating positive contribution for ozone creation [10, 12].

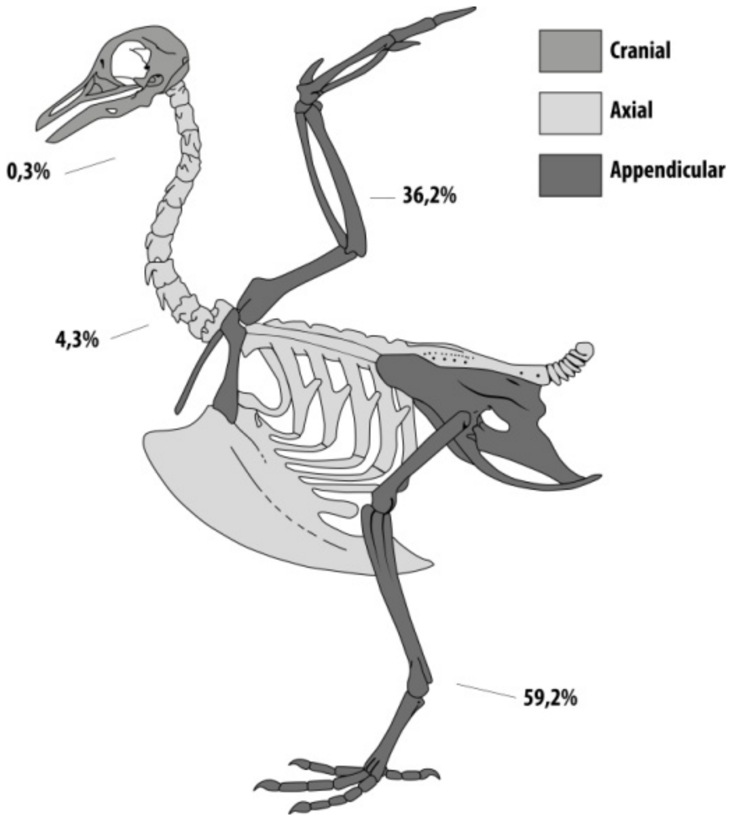

Fig. 2 Quantity and percentage of the skeleton parts represented by bird bones of the Furninha cave.

4.2 Taxonomy

Although the species *T. tadorna* predominates, with 149 bone specimens identified, Furninha cave has a large taxonomic diversity, when compared with other Portuguese Pleistocene sites. The predominant groups are the passerines and the anseriforms. Anseriforms are dominated by marine species (Table 3, Fig. 3), which is explained by the location of the cave.

4.3 Paleoenvironmental Interpretation

Except for the bone of *P. impennis*, which have a fracture that could be of anthropogenic origin, the bird bones from Furninha cave do not provide evidence of human activities (cut marks, effects of fire) [12, 14]. Damage from predation was also not identified. Although the species identified are not typical of caves, they are marine species and the Furninha cave is located on a sea cliff. It is believed that the accumulation of bird remains would have resulted from animals that died inside the cave, but also other remains were brought by other animals and by the primitive humans using this cave. So, the biological remains also contributed to the sedimentary filling of the cave, which mainly consists of sand brought by wind and gravels provided by gravity processes, which would explain the large proportion of broken bones.

The Furninha cave avian assemblage is dominated by seabirds (anseriforms and pelecaniforms). However, the presence of continental species (such as the grey partridge) indicates a connection with continental environments. Species associated with the following environments were identified: coastal habitats, forests, open fields, woods, wetlands and mountain areas.

The presence of birds as the *P. impennis*, *T. tadorna*, *C. olor* and *S. mollissima* point to a colder than present climate. Other bird species, such as *A. crecca* and *N. phaeopus*, as well as mammal species collected in stratigraphic association, suggest humid and hot to temperate climate conditions [9, 12, 13].

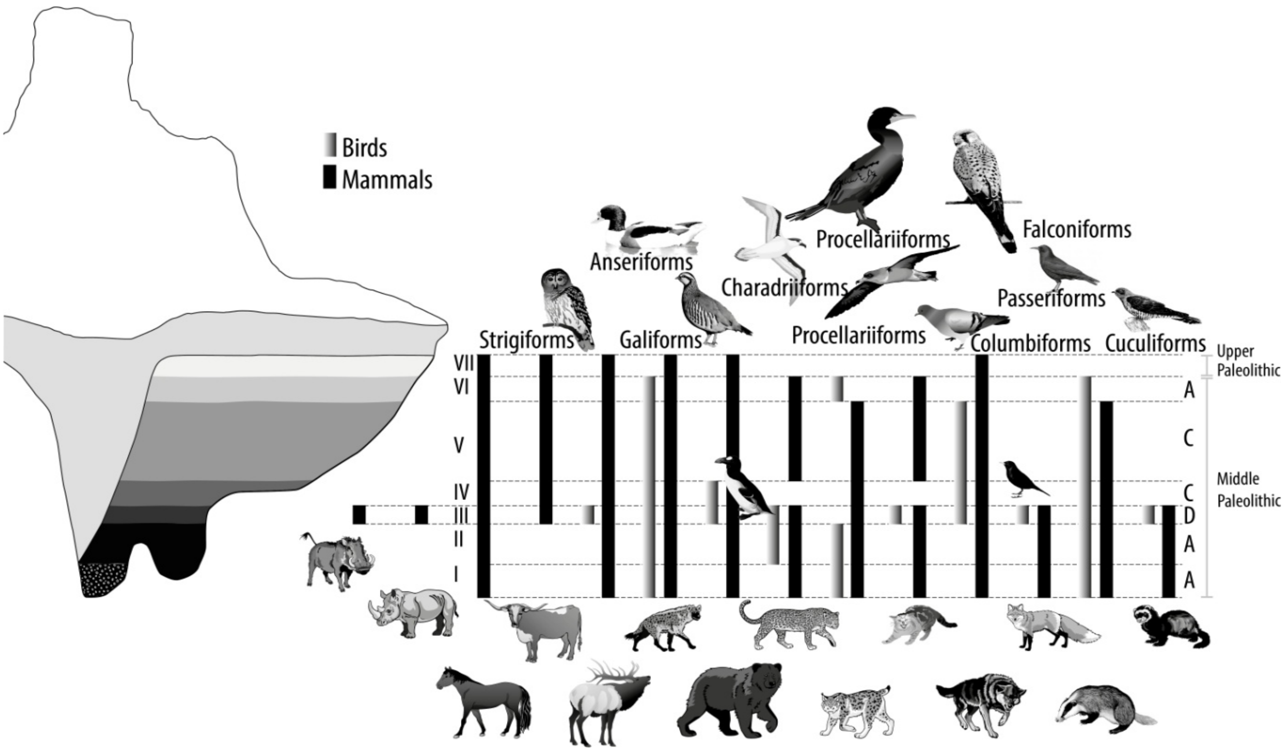

Fig. 3 Distribution of major groups of mammals and birds by the different stratigraphic Pleistocene subunits of Furninha cave, according to Delgado, J. F. N. [1], Brugal, J. P., et al. [10] and Figueiredo, S. [13]

On the right side, the letters indicate the type of climate conditions suggested by the bird species (Table 3). The blue line on the right represents the distribution of Paleolithic industries, indicated by the artifacts found in the various levels. The presence of *Palaeoloxodon* (a fragment of tooth lamella) was identified [13], but it does not have the indication of the layer of origin, reason why its representation in this figure was not placed.

Table 3 List of bird species from Furninha cave, according to Brugal, J. P., et al [10] and Figueiredo, S. [12]

Distribution of species by interpreted environment: A species can occur in more than one environment, in this case it was divided 1 by the number of environments where the species occur (Bos = Woods; CA = Open field Areas; Zh = Wetlands; LAD = Freshwater lakes; Mont = Mountain areas; ZR = Rocky areas; Flo = Forest areas; Cos = Coastal Areas). Climate: A (wet-temperate), B (wet-cold), C (dry-temperate), D (dry-cold).

		Environments								*Climates*
		Bos	CA	Zh	LAD	Mont	ZR	Flo	Cos	
Anseriforms	*Tadorna tadorna*				0.5				0.5	A
	Tadorna ferruginea				1					A
	Somateria mollissima								1	B
	Somateria sp								1	B
	Cygnus olor			0.5					0.5	B
	Anas crecca				0.5				0.5	A
	Anas sp				0.5				0.5	A
	Melanita nigra								1	B
Galiforms	*Alectoris rufa*		1							C
	Coturnix coturnix		1							C
Columbiforms	*Columba livia*						0.5		0.5	C
Charadriiforms	*Numenius phaeopus*			0.33	0.33				0.33	C
	Pinguinus impennis								1	B
	Gallinago sp		0.5		0.5					B
	Larus sp								1	A

Table 3 continued

		Environments								*Climates*
		Bos	CA	Zh	LAD	Mont	ZR	Flo	Cos	
Procellariiforms	*Puffinus puffinus*								1	B
Pelicaniforms	*Phoenicopterus ruber*								1	A
Phoenicopteriforms	*Phalacrocorax aristotelis*								1	A
	Tito alba	0.5	0.5							D
Strigiforms	*Bubo bubo*						0.5	0.5		D
	Asio flammeus	0.33	0.33					0.33		D
	Falco tinuculus						0.5	0.5		C
Falconiforms	*Aquila chrysiateus*		0.33	0.33				0.33		C
	Aquila sp		0.33	0.33				0.33		C
	Gyps fulvus		0.5			0.5				C
	Pyrrhoc. pyrrhocorax					0.5			0.5	D
	Pyrrhocorax graculus					1				D
	Corvus corone	0.33	0.33	0.33						C
	Corvus frugilegus	0.5	0.5							C
	Corvus monedula	0.33	0.33						0.33	C
Passeriforms	*Turdus merula*	0.5	0.5							D
	Turdus philomelos	0.5	0.5							D
	Turdus pilaris	0.5	0.5							D
	Turdus iliacus	0.5	0.5							D
	Turdus sp	0.5	0.5							D
	Pica pica	0.33	0.33					0.33		C
Cuculiforms	*Cuculus canorus*	0.33	0.33	0.33						C
Average		0,42	0,48	0,35	0,55	0,66	0,5	0,38	0,73	C/D

5. Discussion

A relevant highlight is the discovery of a left humerus fragment found in the middle of other bones not classified. This bone has osteological features of the Alcidae family: pronounced longitudinal flat of the diaphysis, lateral and ventral projection of proximal humeral articulation and slightly prominent pectoral crest, compared to dorsal margin. From these features, and from comparison of upper limbs of distinct species of the Alcidae family, it was concluded that this specimen belongs to *P. impennis* [11].

Most of the Pleistocene birds identified belong to taxa still living in Portugal, but only the following species have ceased to occur in the peninsula and its surroundings: *A. chrysaetus*, *C. frugilegus*, *G. fulvus*, *P. ruber*, *P. impennis*, *S. mollissima*, *P. perdix* and *P. graculus*. There are still a few reports of *S. mollissima* from the Minho estuary (upper North coast) to the Algarve, although none in Peniche [23]. These reports must be checked by the PCRB (Portuguese Committee for Rare Birds). The same holds true for *C. olor*, which also occurs around Peniche, but most are probable escapees from captivity. *A. Chrysaetos* individuals prefer high inland mountains, but have occasionally been spotted in the Serra d'Aire e Candeeiros, not far away. *G. fulvus* also prefers inland habitats, but there are records of stray individuals spotted in the Tagus estuary and in an urban environment near Oporto. *C. frugilegus* has also become a rare species in Portugal, only recorded occasionally in the inner south and in the Algarve. It is nonetheless a bird that is common in colder climates. *P. graculus* is completely absent from Portugal, but is very common in several Portuguese Pleistocene assemblages. It is a bird that lives in high mountains above the 1,300 m, which makes the presence of its bones in Furninha remarkable, not because it is close to the coast, but because of the latitude and the altitude as well as the modern-day mild climate of the place. *P. ruber*, an American bird from the Caribbean region, has been separated from the European species, and is about the same size as the *P. roseus*, which in his turn is quite common in the Óbidos lagoon. Although Svensson, L., et al. [24] tell of its presence in Europe, he also claims they are of captive origin; no record from Portugal is known. As older guides [25-27] make no distinction between them, it is assumed that the bones found represent *P. roseus* instead, which is much more plausible.

The subunit III (8.5-9 m asl) has the highest number of faunal remains (mammals and birds) and has the presence of species associated with different climates (warm: *G. fulvus*, *A. rufa* or *D. hemitoechus* and *E. caballus*; cold: *P. impennis* or *P. graculus*) (Fig. 3), suggesting that this stratum was formed over a period of transition from an interstadial to a colder period.

The long period with successive faunal and human occupations of the cave occurred after the cave was above sea level, following the genesis of the marine platform at 15 m asl. The sedimentary filling of the lower lithostratigraphic unit (Pleistocene), which contains Middle Paleolithic to Upper Paleolithic industries (these only at the top) interspersed in aeolian sands, must encompass the period of ca. from 90 to 12 ka. This is supported, although without great precision, by the only absolute date available.

6. Conclusions

Building a bridge to the present-day avifauna hereabouts, it can be concluded that it has barely changed since the Pleistocene. From the analysis of a satellite map from Google Earth, including the Berlengas archipelago and the surroundings up to Caldas da Rainha and down to the São Domingos Dam, and having visited the region, the diversity of ecosystems can be attested, both terrestrial and marine: open sea, islands, coasts with both sand beaches and high cliffs, the harbor itself, and on the mainland agriculture fields both big and small gardens, with a multitude of trees and bushes of several sizes, a few streams, the Óbidos lagoon, the São Domingos Dam and the Paúl da Tornada, a biodiversity hotspot. It comes as no surprise then that from a search on the eBird database for only two of the hotspots in the Peninsula of Peniche (the Carvoeiro Cape and the harbor itself, thus on both sides of the Furninha cave), a total of 162 different species have been identified from the most diverse groups. From the Atlas of Breeding Birds, in its already somewhat outdated second edition of 2008, a total of 119 species are reported to nidify on the area. Both lists include pelagic birds, coastal birds, waders, raptors, and all sorts of smaller birds that are common in Europe.

The identification of *P. impennis* is important, because this is a species associated with a cold climate, and because this species is poorly known in the fossil record of Portugal: Until this identification, it was only known in Gruta da Figueira-Brava and in Porto Santo [28, 29].

The distribution of fauna (birds and mammals) in relation to sedimentary levels allows a study of corresponding paleoclimatic evolution [9, 10, 12, 13].

Acknowledgements

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Histological Characteristics of the Skin and Cuticle of the Wool Fibers in Dubska Pramenka and the Use in Industry

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Abstract: Microscopic analysis of the skin and cuticle of wool fibers in Dubska pramenka show different qualitative parameters. The research study included different parts of the body and the samples of the wool fibers from different regions of the body. Histological description shows difference in the basic structurers of the skin in Dubska pramenka. A very pronounced thin epidermis, while dermis and hypodermis are more developed on the samples from the shoulder. Cornified flakes-cuticle of the root of the tail was of a fine structure, and cornified flakes from the rump showed the features of the rough wool fibers. "Transitional form of cuticle" was dominant on the shoulder. The qualitative parameters have a significant influence on the overall quality of wool in general, and the research contributes to a greater usability value of the wool and development of livestock farming in areas in a broader sense.

Key words: skin, cuticle, Dubska pramenka.

1. Introduction

Skin is the largest organ and it covers the entire body. It consists of epidermis, dermis and subcutaneous tissue or subcutis. The structure of skin in domestic animals is not equal, primarily, the epidermis-dermis ratio varies, the presence and thickness of subcutaneous connective tissue. Difference in histological structure of some areas of the body is also present in the same animals [1]. Wool, which is a product of the skin, is made of a set of wool fibers. The surface of the wool fibers contains cornified cells, flakes, i.e. cuticle. Katica, A., et al. [2] studies that focused on the structure of the skin and the characteristics of the cuticle found differences in the structure, especially in the outer layer of the skin—epidermis, and the appearance of the cuticle, which varied depending on the region of the body. In general, total quality of the wool depends on the qualitative parameters of the skin and fibers and so does its classification and theuse in the processing and development of livestock farming in areas.

2. Material and Methods

The samples for microscopic examinations of the skin and fibers of Dubska pramenka were taken from Vlasic mountain in Central Bosnia. The animals were reared under nomadic conditions, at the latitude of

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850-1,600 m. The animals were healthy with a good body condition, weighing between 50 and 65 kg, above three years of age. Nutrition of the sheep was usual for nomadic conditions during summer, with the addition of grains before estrus, in line with the research studies [3, 4]. The samples of the skin for histological analysis were taken from the middle of the last left rib, the shoulder, the rump and the root of the tail according to the Markotic method. A moment before sampling, the site was previously shaved, washed and disinfected, and skin cuts with subcutis were prepared, 6 mm in diameter. The samples were placed in plastic bottles with caps that contained 10% formalin until histological processing i.e. molding into paraffin blocks. Histological preparations of the skin were prepared according to the usual sample preparation protocol for optical microscopy observations. The analysis of the microscopic skin preparations was performed using binocular optical microscope MOTIC TYPE 120M with magnification of 100, 200 and 400 times. The fiber for microscopic analysis was taken from different parts of the body: the shoulder, the rump and the root of the tail, cutting the wisps next to the skin. Prior to microscopic examination of the cuticle, all mechanical dirt is cleaned; the samples were washed with neutral soap and rinsed with water, and then rinsed with distilled water. After that, the samples were immersed in hydrogen peroxide for 24 hours, then in xylol for 48 hours. These treated samples were rinsed with distilled water and left to dry. The processed samples were placed on the glass slide, embedded into glycerin and examined under the microscope. The fibers were analyzed with binocular optical microscope, with magnification of 100, 200 and 400 times.

3. Results and Discussion

Microscopic analysis of the Dubska pramenka skin was performed using epidermis, dermis and hypodermis. Using descriptive presentation, the particulars of the skin of Dubska pramenka were singled out from different parts of the body. Microscopic examination of the skin of the Dubska pramenka taken from the shoulder identified a very thin epidermis, with dermis and hypodermis well developed. The attention was focused on dermis and in that particular segment, that the presence of hair follicles grouped in sets of two or three follicles (one central and two peripheral) and rarely asingle follicle was found [5]. Reticular dermis contains collagen and elastic fibers that give dermis the appearance of compactness (Fig. 1). Sebaceous glands (Glandulae alveolares) are immediately next to hair follicles. Sweat glands are surrounded by the elements of connective tissue where adipocytes can be seen [6].

The analysis of the sample fibers from the shoulders shows a so called transitional form of cuticle (Fig. 2). The cornified flakes are rather large with multi-corners, and the clearly pronounced edges are merging forming a whole.

A thin epidermis is characteristic on the rump of Dubska pramenka. Dermis is well developed, with connective tissues and notable nuclei of the smooth muscle cells. The compacted collagen and elastic fibers are present in the papillary layer, while hair follicles are surrounded with poorly developed sebaceous glands, which are globular or elongated (Fig. 3).

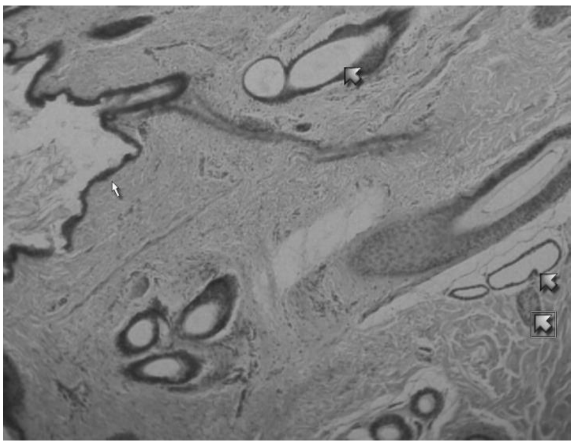

Fig. 1 The skin of the shoulder (Dubska pramenka); the white arrow indicates dermis; the blue arrows indicate sweat glands; the green arrow indicates sebaceous gland; HXE, × 200.

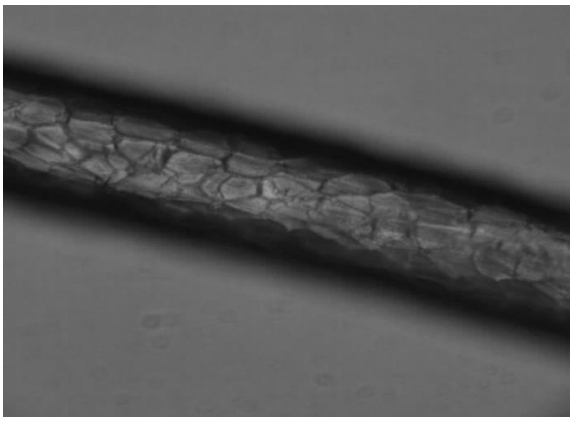

Fig. 2 Native preparation; × 400; shoulder.

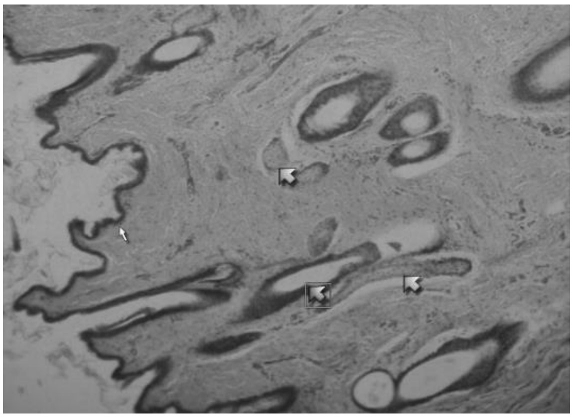

Fig. 3 The skin of the rump (Dubska pramenka); the white arrow indicates epidermis; the blue arrow indicates hair follicle; the green arrow indicates sebaceous gland; HXE; × 200.

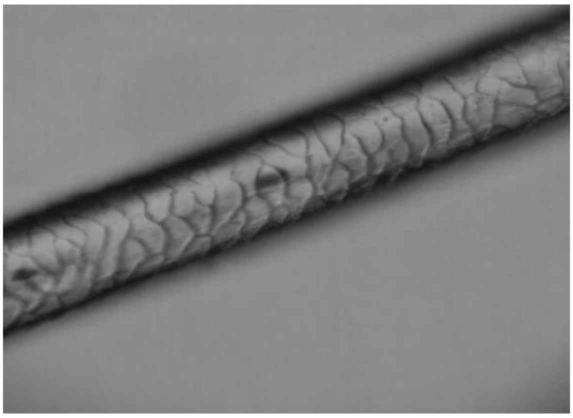

Fig. 4 Native preparation; × 400; the rumps.

On the wool fiber samples taken from the rump, cornified flakes overlap continuously (Fig. 4). They have irregular shape reminding of roof tiles. This appearance of the cuticle most frequently is associated with rough wool fibers.

Epidermis of the root of the tail is notable, but without clear strata. Its surface shows a layer of squamous cells, darker in color, flat, interconnected. This layer makes the stratum corneum, made of cells without nuclei, with cytoplasmic inclusions of keratin. The skin of the root of the tail shows clearly visible outer cells separated from other layers that do not have clear edges, and they make stratum disjunctum. Dermis is rich with oval hair follicles with developed sebaceous glands. Loose connective tissue is present in the outer papillary layer, while deeper dermis layers also contain collagen fibers (Fig. 5).

Cross sections of sebaceous glands are noted (Glandulae glomiformes), which is highlighted in the studies by Janquera L. C. [7]. The studies to date indicate that the distribution of sebaceous glands in this part of the skin may affect the quality of leather, leather industry, as it leads to separation of the papillary section from the reticular section of the dermis, which affects the quality of the final products in leather industry.

Cuticle i.e. flakes on the fibers from the root of the tail are significantly smaller, of finer structure, (Fig. 6), especially in regard to the ones from the rump.

Infundibular appearance of circularly arranged cornified flakes may be seen on the edges of the wool fibers (Fig. 7).

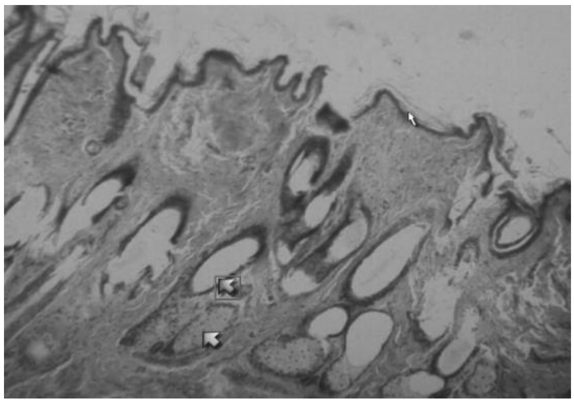

Fig. 5 The skin of the root of the tail (Dubska pramenka); the white arrow indicates dermis; the blue arrow indicates hair follicle; the green arrow indicates sebaceous gland; HXE; × 200.

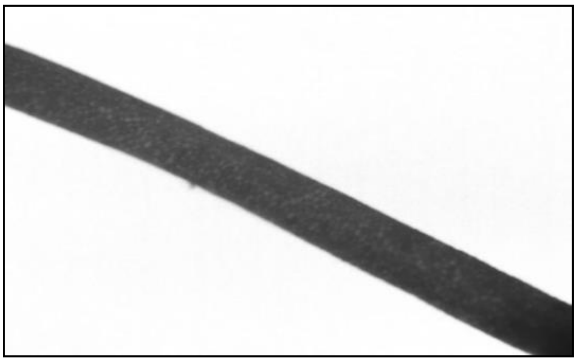

Fig. 6 Native preparation; × 400; the root of the tail.

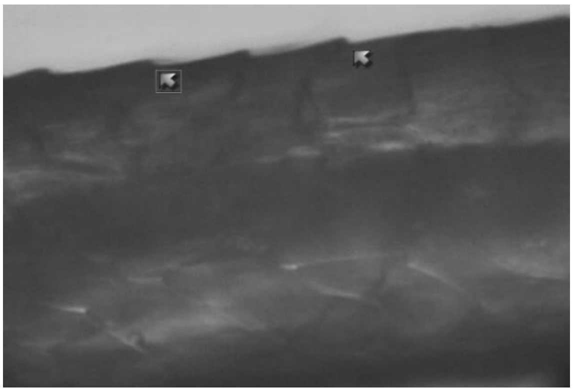

Fig. 7 Native preparation; immersion; distribution of flakes; the root of the tail.

This appearance is a characteristic of a finer high-quality wool, which contributes to high-quality classification bearing in mind the quality of the final products of the textile industry.

4. Conclusions

Description of histological preparations of the Dubska pramenka skin showed the following distinctive features: thin epidermis with developed dermis and hypodermis—the shoulder samples. Compacted collagen and elastic fibers are present in the papillary layer of dermis of the skin from the rump, stratum corneum and stratum disjunctum of epidermis of the skin from the root of the tail are clearly visible unlike in other layers. The studied samples of the wool fibers show certain differences in the form and position of the cornified flakes—cuticle depending on the region of the body. The cuticle of the root of the tail was of a finer structure; cornified flakes on the rump showed the features of rough wool fibers, and the "transitional form of the cuticle" was dominant on the shoulder. Distinctive features of the skin structure and appearance of the cuticle of the wool fibers of Dubska pramenka may be used as comparative advantages in the utilization of new raw materials in different industry branches and may directly influence improvement of production in livestock farming. Considering that skin has multiple functions in an organism and together with cuticle, it accentuates its protective role, it directs the further use of wool as an important ecological raw material.

Acknowledgement

The study is likely to have an impact on total production and use of raw wool as the main raw material in the demanding textile industry, which from an environmental point of view, is a major problem both in Bosnia and Herzegovina, as well as in neighboring countries.

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Complex Use of the Water Spring Istog

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Abstract: While living in the century of crisis (of energy and water), more focus should be given on renewable energy. Since Kosovo is more limited in hydro-energy resources than the neighboring countries, it is essential to study them and put to use more efficiently. Subject of this study is Istog spring as it is the most important spring of Mokra Gora together with Vrella and White Drino. The spring is analyzed as a complex resource on water economy providing: fish (trout), potable water, water for irrigation and hydro-energy (currently not in function). The focus of the study remains the hydro-energetic component, not just a revitalization process but as an upgrade of the existing facility to increase the capacity by 2-3 times. This study is based on information selection and processing regarding detailed technical and economic analysis providing a method for other springs that will be studied in the future. Two technical solutions to the problem are provided as the best economical and technical solution. Solution 1 has one level and a calculated flow of 7.5 m^3/s and consists generally of renovation works on existing facilities; Solution 2 plans the construction of another level 3 m lower than the existing one, increasing so both the hydro-power capacity and implementation cost for the project. Both solutions provide little to no impact on the spring main attributes. The valley ecology will not be influenced because the water after HPP (Hydro Power Plant) will be flowing in its own bed. After this study, Istog spring will be more attractive to donors and will contribute in improvement of energetic structure in Kosovo that for the time being is poor in hydro component.

Key words: Water, hydro-energy, environment engineering, complex use and sustainable management, HPP (Hydro Power Plant).

1. Introduction—Current State of the Spring and Compositions on the "Istog" Spring Hydrology System

1.1 Current State of the Spring and Possible Changes for Rational Use

1.1.1 Principals, Obstacles of the Hydropower System

Energy, water sectors and other public services suffer from long-term neglect in management, maintenance and investment in the physical capital. The most important parts of the system are approaching the end of their shelf-life. They are all under the theoretical capacity and there are large gaps in water supply and particularly in the hydropower system.

The hydropower system is based on the establishment principle as a stable supplier of self-effective management services, providing unbiased and reliable public services supply that meet the standards. Developing and managing water sources systems involves making decisions. Water sources systems typically provide a variety of economic, environmental and ecological services [1].

Consumers have not accepted yet the responsibility for payment of public services they use and that poses an obstacle to making progress towards the free market.

De The Istog spring is a facility comprising of a few elements that have undergone several changes in the course of its use (Figs. 1 and 2). There have been changes made throughout its structure until reaching its current state. The schemes of the flow intake are performed at two levels (Fig. 2).

The inflow composition is an arched weir of diameter 40.00 m, length 53.00 m, height 8.00 m.

The catchment facility in the Istog spring is in good condition, both the integral structure and the cumulative water amount (Fig. 3). It is difficult to

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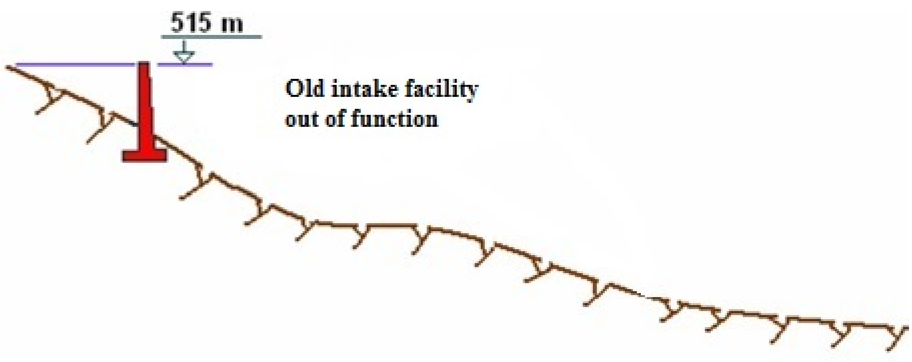


Fig. 1 Out of function in the 515 m quota.

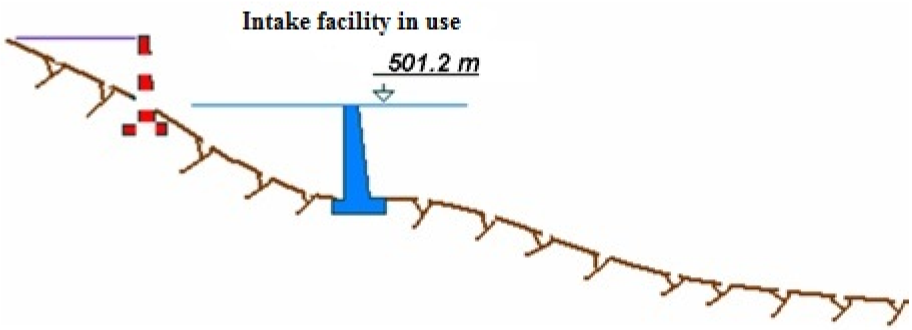


Fig. 2 The scheme in use in 501.2 m quota.

Fig. 3 Photo of dam in catchment facility.

make any changes in this facility. These changes will bring about the deterioration of the work regime of the spring itself.

The solution required for the catchment of the water amount overflow is required at the lowest level, establishing another water catchment facility, to collect overflow water from the main facility as shown in Fig. 3.

1.1.2 Possible Changes on Inflow Composition

There is a small difference between quota of the inflow facility and the height of the water outlet from the spring, which stipulates the elevation of the weir height, leading to the flooding of the spring and the deterioration of its own regime.

In order to use the non-accessible water from this composition, an inflow facility should be build at a level slightly below the current facility (see Fig. 4 for two-level exploitation).

1.2.1 Kosovo Energy System

There is only one supplier of electricity services in Kosovo, KEK (Kosovo's Energy Corporation). The main priorities are emergency repairs and maintenance to support as much as possible the power generation system yearly. Thus, the basis of the energy system in Kosovo is the thermo-element.

In terms of this, it is the best opportunity to raise the issue of non-usage of water power in Kosovo even though, in comparison to e.g. Albania, water resources and consequently hydropower reserves are smaller.

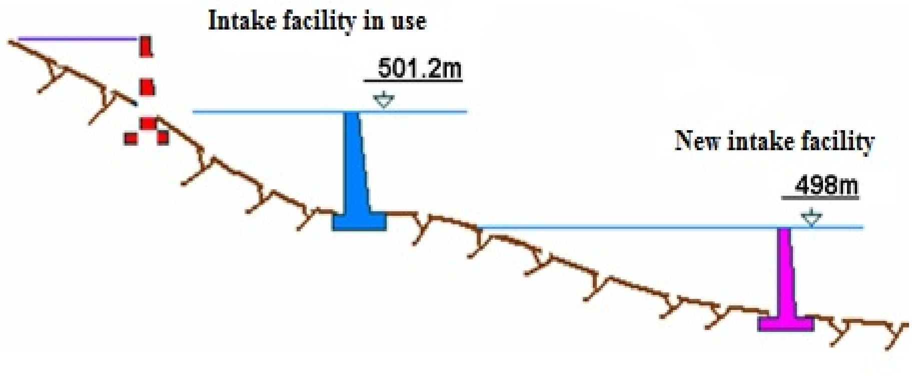


Fig. 4 The new scheme that would use all the amount of water.1.2 Current State of HPP (Hydro Power Plant) and Its Constituent Facilities.

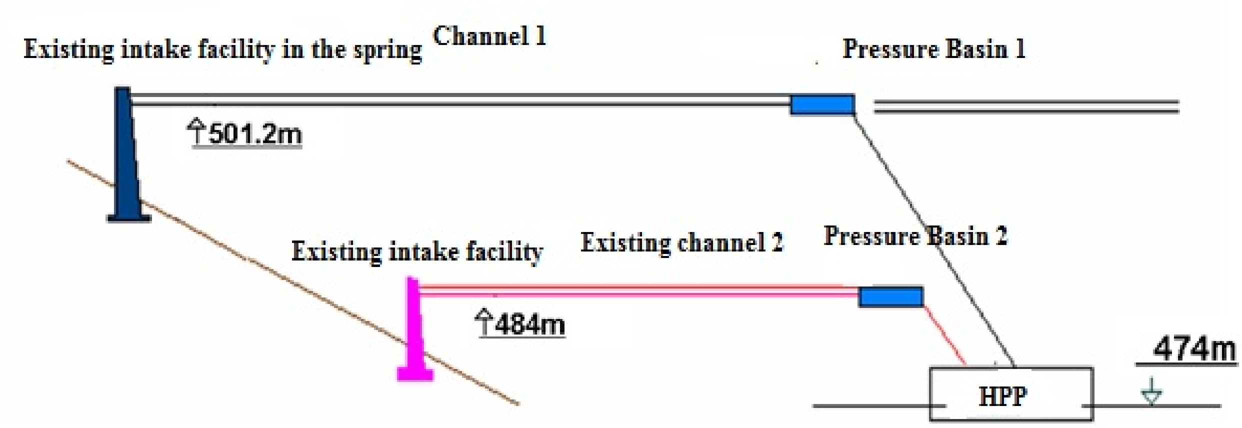


Fig. 5 Current hydropower scheme.

1.2.2 Current State of HPP and Its Constituent Facilities

The current scheme has been built in two levels (Fig. 5). The HPP building is located at 474 m quota where the use is made at the first level with 10.00 m incidence.

The current use scheme comprises channel 1, flowing water from catchment facility to the P.B. (Pressure Basin) 1 using the incidence of 380 m longitude.

Catchment facility in channel 2 to the P.B. 2 using the incidence of 10.00 m, 135 m longitude [2]. The water from the two pressure basins flows to HPP through a pipeline.

1.2.3 Channel of Water Inflow to the P.B. 1

This channel performs a double function. It is used in agriculture between June and September and for hydropower the rest of the months throughout the year. The water amount in the channel is 2.00 m^3/sec. The channel was totally reconstructed, bringing it to the parameters required by the two sectors (Figs. 6 and 7).

Fig. 6 Photo of water transport channel.


Fig. 7 Existing channel.


Fig. 9 Amortized pipeline.


Fig. 8 Photo of hydropower building.


Fig. 10 Turbine out of function.

1.2.4 HPP Building

From the physical standpoint, the HPP building is a solid structure (see Fig. 8). Considering also its current state of high parameters and with an internal architecture, capable of withstanding the further use and starting from the HPP building—the optimal facility parameters on the energy and economic basis will be retrieved.

1.2.5 Pipeline Network of Water Intake to the HPP

The entire pipeline systems are completely non-operational and depreciated, and they could not be made operational (Fig. 9). These pipelines will be replaced with the investments to be made.

1.2.6 Old Turbine Type

There are two turbines in the HPP building (Figs. 10 and 11). They are non-operational due to serious depreciation and lack of maintenance.

RADE KONCAR, S 1004–8
400 KVA, COSφ=0.8, 680A,
750 rrot/min

RADE KONCAR 905–12
60 KVA, 230 A, COSφ=0.8,
500 rrot/min

Fig. 11 Properties of the existing turbine.

These turbines are physically out of work and it would be impossible making them again operational or that could be achieved at very high costs and very low unjustified efficiency in the conditions of nowadays energy market.

1.2.7 Channel of Water Outflow from HPP

The channel is located on the left side of the HPP building and it is not concrete lined, although it is able to withstand the amount of water used.

1.2.8. Channel of Water Inflow to the Fish Farms

Upon water outflow from HPP, the water, with an intake composition, flowed in through the concrete lined channel to the fish farm reserve (Fig. 12).

1.2.9 Istog River Valley

Following the HPP building and the intake water composition for the fish reserve, the water permeates quietly through the valley of the Istog river (Fig. 13).

Generally, there are no erosion problems on river banks, which are mostly protected by trees and protective measures against the erosion occurrence. Such phenomena could be observed in the downstream where frequent flooding occurs.

1.2.10 Possible Changes of the Facility

In order to utilize the maximum amount of entire water flowing into the spring, after meeting the basic needs of water customers or users from this spring, various solutions on energy utilization of surplus water have been examined.

Carrying out the necessary comparative analysis, the most effective solutions for the effective maximum use were brought to attention.

The proposed new one-step scheme is shown in Fig. 14.

Two-scale scheme 2 (Fig. 15) by changing the current scheme, the first scale at 501.2 m quota with the current channel and the second scale at 498 m quota with steel pipeline with 315 m length is shown in Fig. 15.

Fig. 12 Reserve of trout in Istog.

Fig. 13 Istog river valley.

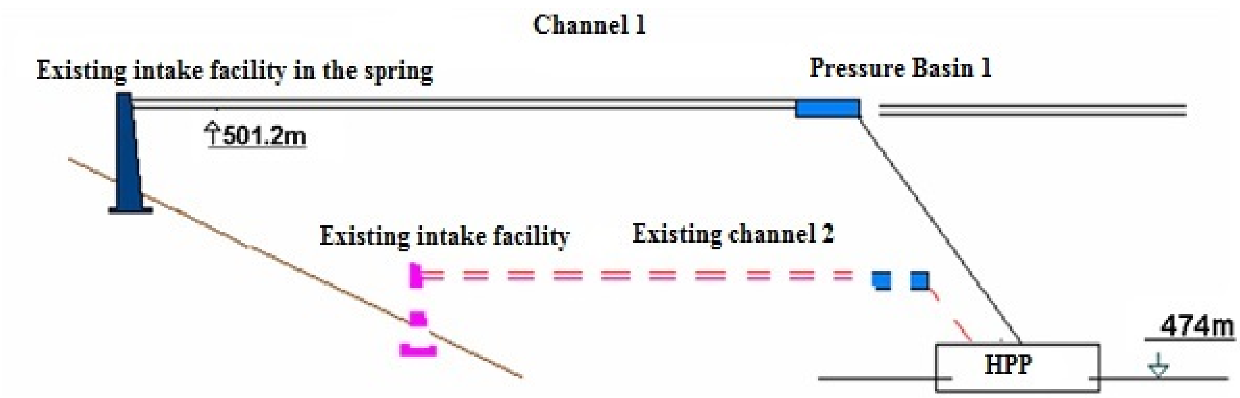


Fig. 14 Scheme with one degree of exploitation.

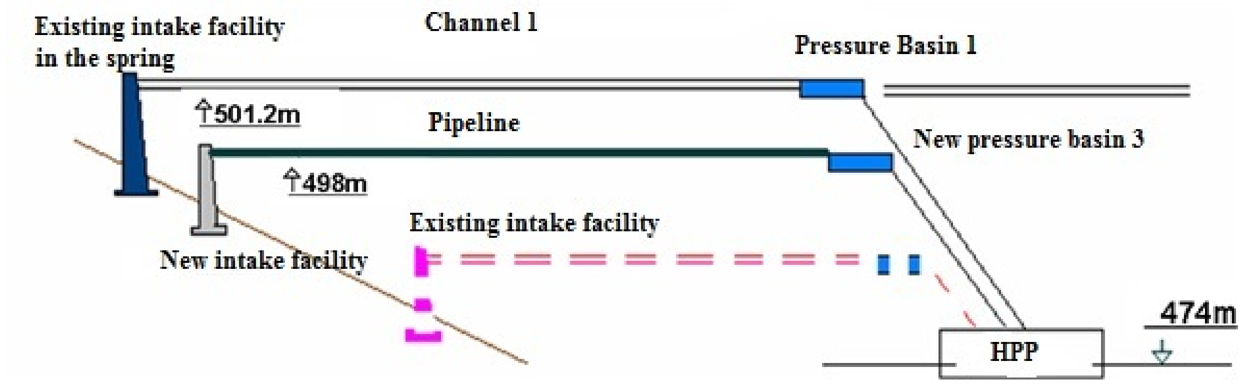


Fig. 15 Scheme with two degree of exploitation.

2. Hydrological Study on the "Istog" Spring

2.1 Hydrology of the Istog Spring

The hydrological study aims at recognizing and evaluating the overall water potential of the country and the laws of this potential distribution in space and time. The utilization of the hydrographic water network for the needs of economic and cultural development must be preceded in order to recognize this value, without allowing the abundant waters of streams and rivers, being a gift of nature, to flow in vain, without utilizing their usefulness for hydropower, irrigation, water supply of population and industry, recreation etc..

The aim of this paper, relying on the processing and homogenization of a multi-annual comprehensive hydrometric material for the period 1938-1992, was to assess both the watercourse of the Istog underground spring and its relation to the physical-geographic factors of the catchment basin. The watercourse is the most important element of a water resource. It also determines, better than any other element, the ability of the resource to be used for different purposes.

Waters of the hydrographic network of the Istog spring are widely used for drinking water supply to population, irrigation of agricultural lands, industry, energy, fish farming, etc..

2.1.1 Physical-Geographic Conditions of the Catchment Basin of the "Istog" Spring

The Istog spring is one of the main underground springs of the Kosovo hydrographic network. The hydrological regime of the spring is closely related to physical-geographic characteristics of the catchment basin.

The main physical-geographic characteristics of the catchment basin, affecting the hydrological regime of this spring are as:

- Geographic expansion to the catchment basin;
- Relief;
- Hydrography;
- Geology;
- Pedology;
- Tectonics;
- Vegetation cover;
- Geographic distribution of climate elements.

2.1.2 Geographic Expansion to the Catchment Basin

The catchment basin that forms the Istog Basin is located on the northern part of Dukagjini plateau, between the parallels 42°40' and 42°70' of the northern latitude and the 30°21' and 30°20' meridian, 42° eastern latitude [3]. It includes approximately 1/9 of the entire surface of the plane. The northern part of Istog river basin lies in Accursed Mountains and a good part at Dry Mountains. Its altitude reaches 1,758 m at the peak grape, followed by Dry Mountains in the north-western part, with the highest peak of 2,154 m above the sea level. It lies entirely in the territory of Kosovo, with the general flow course from north-west to south. Located in the south of the "Mokra Gora" Mountain (the Wet Mountain), the Iber river lies in the north over the mountains, in the underground spring

Vrelle. The basin is 53% mountainous and 47% field area. The surface of the catchment basin is 440 km^2 and the river basin is 216 km^2. The basin has very convenient connections to the second and third category routes, located in the southern and central part of the basin.

2.1.3 Relief

The configuration features of the catchment basin of the Istog spring are determined by the geographical expansion of the basin area. The altitude of the spring in 520 m quota above the sea level shows that this spring collects waters of a territory with an emphasized mountainous character. The highest point is about 1,500 m above the sea level. The expansion of the basin creating the Istog underground spring is 76 km^2, and altimetric position over 1,500 m. Its area is 52 km^2 at 1,000-1,500 m quota about 22 km^2, under 1,000 m with 2 km^2 area, karstic part of the catchment area of 6 km^2, feeding the Istog spring [4].

2.1.4 Hydrography

The hydro-graphic area of the Istog spring catchment basin consists of a completely underground network. This area is characterized by small springs flowing to its main effluent, which is the Istog spring itself and consisting of two adjacent springs. In various periods, there are fluctuations of water quantities in these springs. During the period of inflow measurements, Q = (1.19-4.9) m^3/sec are observed, the minimum inflow rate is recorded between September to October 1933 (1.6-1.8) m^3/sec which continued for about 50 days and the maximum inflow in 1936 is about 6.6 m^3/sec [5]. The annual volume flowing into Istog is (75-126) × 106 m^3. The use of the spring is complex. It is used for drinking water supply, agriculture and trout reserve. It was also used for hydro-electricity in the past.

In regards to the water used for HPP, there is a possibility in taking more water and at higher levels.

The Istog spring is the first spring in the Dukagjini hydrographic network, joining other effluents which are generally underground springs of the Vrella spring, the White Drino spring, Bistrica of Peja, Bistrica of Decani, creating the White Drino river, which percolates to Albania.

This network is considered as the richest one with groundwater basins. The comparison of hydrological conditions of the hydrographic network shows that they have made the accumulation and rational use of water resources possible, land protection from flooding, water systematization in terms of agricultural intensification, etc..

2.1.5 Assessment of Hydrology in the Catchment Basin Forming "Istog" Underground Basin

As a result of climatic factors, the regime of flow distribution throughout the year in the Istog spring is largely formed by rainfalls, soil surface factors, mainly by the relief of geological formation.

The first observations carried out by the department of Peja water measurements belong to the years 1933-1940. Measurements were made by an engineer called Burovic, whose values are reliable because the measurements were made with overflow facility.

Figs. 1 and 2 show annual flow course of the years 1933 to 1940, and 27 years for recorded measurements.

Fig. 3 shows the evolution of the average flow of 27 years.

Maximum and minimum values were recorded from the observations made for the years 1933-1940 (Table 1) and 1957-1959 (Fig. 16).

Maximum annual inflow Q_{max} = 4.0 m^3/sec [6].

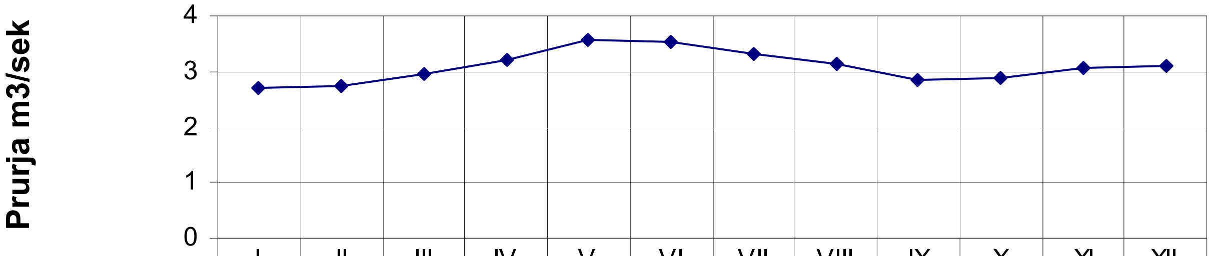
2.1.6 Geology

From the previous studies, it was concluded that this pond was built entirely of thick plaque limestone. Karst springs were formed as a result of geological formation. This composition has conditioned a radial extension of the small karst pits and troughs of 1,500 m thickness, on which a flavio-dolomite broad plane is formed.

Two corrugated directions were combined in this section: the direction of characteristic abbreviations table on Accursed Mountains and karstic rocks direction,

Table 1 Average monthly inflow 1933-1940.

	Monthly avg. inflow 1933-1940							avg. 3.09 m^3/sec				
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Inflow (m^3/sec)	2.72	2.75	2.96	3.19	3.57	3.53	3.3	3.12	2.84	2.88	3.05	3.09



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
m3/sek	2.72	2.75	2.96	3.19	3.57	3.53	3.3	3.12	2.84	2.88	3.05	3.09

Fig. 16 Average monthly flows 1933-1940.

which is known as dynamic management, characteristic for the Paleozoic formations. In general, they dominate the limestone rocks composed of $MgCO_3$ magnesium, Ca calcium and dolomite.

This block represents the highest and the most magnificient part of "Dukagjini", the Kosovo Alps, situated in the center of them.

2.1.7 Pedology

The surface of the catchment basin of the Istog spring, for its own meridian extent and rugged relief, in terms of pedological aspect, is formed of different types of soil.

Pasture and carbonated-humus lands are located on the altitude of 1,000-1,200 m above sea level. These lands, mechanically placed under the pasture alpine and subalpine vegetation, represent the upland surface source. These soils occupy a small area of the total territory of the catchment basin of this spring. Brown forest lands, stretching at 700-1,000 m height above sea level, that are mechanically placed under beech, chestnut, Mediterranean fir vegetation etc. represent about 18% of the forested area.

These soils are permeable and of high hydro-capacity. These lands are distinguished by low content of humus. For the most part, the soil cover or the humus layer is very shallow or absent. Consequently, these lands are more easily subject to the erosion process, as due to the superficial mechanical action, they detach more easily from the surface of the catchment basin, therefore, large infiltration occurs due to this phenomenon. As a result of the pedologic construction, the catchment basin that forms the Istog spring is generally easily subject to the erosion process.

2.1.8 Tectonics

The Dukagjini Plain (Rrafshii Dukagjinit) has gained the shape of its territory in the newer era of geological formation. Its forests started to be formed in the Diogenes corrugation towards east-west and north-south-west alignment. The tectonic predisposition has defined the basic contour elements. Radial movement in this region is reflected in orogenies of the mountainous territory to the west and south. Small and large slides are observed in this area. Since its creation to date the tectonic-geomorphology shape has seen many major modifications and they have lost the shape of the previous initial relief.

Parts of these mountains are not as rugged and harsh as before. Now they are more rounded and increasingly losing their previous shapes.

2.1.9 Vegetation Cover

Another characteristic is also the scarce vegetation cover.

By vegetation cover, the surface of the catchment basin forming the Istog spring is divided into different phytoclimatic areas.

Phytoclimatic area of subalpine pasture is situated in the catchment basin territory and located at 1,000 m altitude above the sea level.

Shrub area lies at lower altitudes, or in the lower area of the territory.

Beech, oak, phytoclimatic areas lie at 900 m altitude, and the chestnut, white pine area lie at 700-900 m above the sea level.

This area covered by vegetation continues merging with the surface of the catchment basin of Vrella. These two underground basins are the main effluents forming the underground basin Lubozhde. Therefore, most of the trees are deciduous and protect land slightly from the action of meteorological agents. Forest massifs are mostly poor, they are rare, not uniformly distributed across the surface, and consequently, they are not able to collect large quantities of water and make the evaporation process intensive.

2.1.10 Geographic Expansion of Climatic Elements

2.1.10.1 Climatic Position

Due to its mountain extent, the surface of the catchment basin falls under the humid sub-tropical belt. Significant climate changes have been observed, expressed in the gradual transition to the average continental climate zone of the Central Europe. The main elements conditioning the climate catchment regime as precipitation, air temperature, humidity, etc. are characterized by an annual course more or less designed, depending on the height of land above the sea level, the geographical scope of the basin from the intensity of atmospheric circulation. The area is characterized by cold winters and long duration. The snow there is an ordinary occurrence, while the height of snow layer reaches up to 2 m.

2.1.10.2 Air and Water Temperature

Air temperature is one of the main factors characterizing the thermal regime of the basin. Analyzing the dependence of the thermal regime with physical-geographic characteristics of the hydrographic basin territory, a conclusion that in general, there is a connection to some extent between the altitude of the country and the height of air temperature is reached, however, the character is regional in nature. Average lowest annual temperatures observed are 11.3 °C. The main factor of temperature change in this area is altitude and geographical position. It turns out that the coldest month is January and the warmest is June-July.

Average annual water temperature is 7-9 °C.

2.1.10.3 Rainfalls

They are main hydro-meteorological characteristic and their distribution in space and time greatly influence the flow regime, because it directly affects filling up water reserves on the land surface and underground. The main features of the pluviometric regime of a geographic region can be recognized by the average annual values. The part where the Istog catchment basin lies is included in the area characterized by the largest average annual amount of rainfalls, where annual rainfall reach up to 1,500 mm/year. The largest amount of precipitation falls in December and the lowest in June.

Precipitations in the form of snow fall mainly during winter months, and their sustainability depends on local weather conditions and air temperature.

2.1.10.4 Solar Radiation

Data analysis shows that the intensity of the total radiation for unclouded weather conditions has regular annual performance. The maximum intensity value is in July, and the minimum value in January. Total maximum radiation along the territory is 24.79 kWh/m^2. Minimum falls down to 24.79 kWh/m^2.

3. Environmental Impact

One of the contemporary issues in the construction of engineering works and in particular of hydro-technical works is the environmental impact study.

In western practice, there are different methodologies developed to assess the environmental work impact, amongst which is the NNC (National Research Center—Italy) under which the environment is studied by components and factors according to Section 3.1.

3.1 Natural Constituents

3.1.1 Physical Constituents

The physical constituents are surface waters, ground waters, soils, climate, lithology, geology, air and noises.

3.1.2 Biological Constituents

The biological constituents are mammals, fish, amphibians, reptiles, birds, insects, microorganisms, herbal vegetation, shrubs, natural vegetation and crops.

3.2 Socio-economic Constituents

The socio-economic constituents are population, exodus, culture, archeology, residential zone, health, safety, industry, trade, services, tourism and agriculture.

This is a current and present methodology in Europe and widely, however it is less known and not used at all in Kosovo and Albania.

Certainly, weirs and reservoirs hydro-technical actions make a contribution to the environment, however, derivation hydropower actions also have an impact, which should be assessed both in positive and negative terms.

The essence lies in the assessment causality-consequence of the interaction work-respective territory.

As seen from Section 3, the main components are component of the natural environment (includes physical and biological component) and socio-economic component.

These components have their own factors, which should be identified and assessed before and after the implementation of the project.

What is important in this methodology is the use of assessment “weight attribute” criteria factor, namely, the impact of the project on each factor is assessed not only for quality, but also for quantity. Thus, each factor is given appropriate relevance in relation to the others, reaching finally an “IQUAM (Final Weighted Environmental Quality Index)”.

The main procedural stages of an environmental compatibility study shall be:

(1) Preliminary researches;

(2) Description and identification of actions and factors;

(3) Weighing attribution;

(4) Impact assessment;

(5) Data formatting;

(6) Final assessment.

Meanwhile, in order to reach to IQUAM, the genric environmental structure is developed at four levels as shown in Table 2.

In order to assist the methodical application, the ICOLD (Italian National Commission on Large Dams) has also made the list of designing actions and use of compositions. This list shall be used as a standard in the EIS (Environmental Impact Study).

3.3 Water Use

The water use are irrigation, energy, drinking water, regulation of rivers, industrial use, sailing, use against fire, fishing, sport use and environmental various use.

3.4 Physical Factors

The physical factors are weir presence, reservoir, water diversion, construction site, dikes, buildings, deforestation, closure, channels and pipeline, water outflows, inflow and diversion actions, transmission lines and unconventional materials.

Table 2 Generic environmental structure levels.

At level zero	General environment
At level I	X, Y, Z systems.
At level II	Components for every system
At level III	Factors for each component

3.5 Areas of Interest

The areas of interest are flooded areas, lake banks, water level oscillation in the lake, upper part of river, lower part of river, irrigation channels, ground waters, sea coast and lower part of river connected to the basin.

3.6 Corrective Actions

The corrective actions are phology repopulation , guaranteed river flow, tourism development, water level control, infrastructure, reforestation, erosion control, river deepening, weir, outflow, auxiliary weir, compensation reservoir, barriers against floating bodies, basin protection, water treatment, improvement industries, transfer of population and area of protection from avio fauna.

3.7 Normative Predictions

The normative predictions are national laws, regional laws, urban regulations, contributions and taxes and immovable property values.

3.8 Interrelation Factors

The interrelation factors are: inter-regional reservoirs, inter-municipal reservoirs, benefits for other regions and benefits for other municipalities.

The quality impact assessment is also performed in the order shown in Table 3.

Authors emphasizes that the application of this methodology (in particular the section of relevance assessment—weighing of each factor or component that is based on "pair" factors confrontation under the formulated technique by SAAT (Sanitation Approach Advise and Training) is not simple and certainly, its depth depends also on the stages of the project.

In this case study, several possible estimations have been made, especially qualitatively, without analyzing the quantitative part of the environmental impact. Certainly, this action also requires fulfillment in compliance with the proposed methodology, however this will be implemented in further stages of the study—design on the complex use of this water source.

Table 3 Quantity impact assessment

Type of impact	Symbol	
Impact	Positive	+
	Negative	-
Effect	Irreversible	P
	Reversible	K
Duration	Continuous	V
	Temporary	P
Area of impact	Zonal	Z

4. Energy Development Strategy

The strategy pursued in the public service sector aims to replace the periodic cycle in emergency aid to a gradual process of a sustainable development. The main goal in the public service sector is the establishment of sustainable providers of public services with effective self-management in defense and the public interest services by providing impartial and credible public procurement, meeting proper health, safety, environmental services standards with reasonable prices for all customers. An important and quantifiable criterion for plan is the economic benefits and costs a plan would entail when it implemented [7].

There is only one provider of electrical services (KEK) in Kosovo. The top priorities are urgent repairs and maintenance to support as much as possible the power generation system for the winter period. There have been extensive studies on long-term capital and operational opportunities and future needs. Detailed reviews have been made on the overall state of the system in all aspects.

Planning has triggered discussions and mid-term and long-term projects on the initiation of a project—a comprehensive study covering a long-term period.

4.1 HPP Location

The composition actions of the hydropower node are located on the left side of the Istog river valley (Fig. 17). The inflow composition is 501.2 m and at 498 m quote, the channel is directed to 501.2-500.2

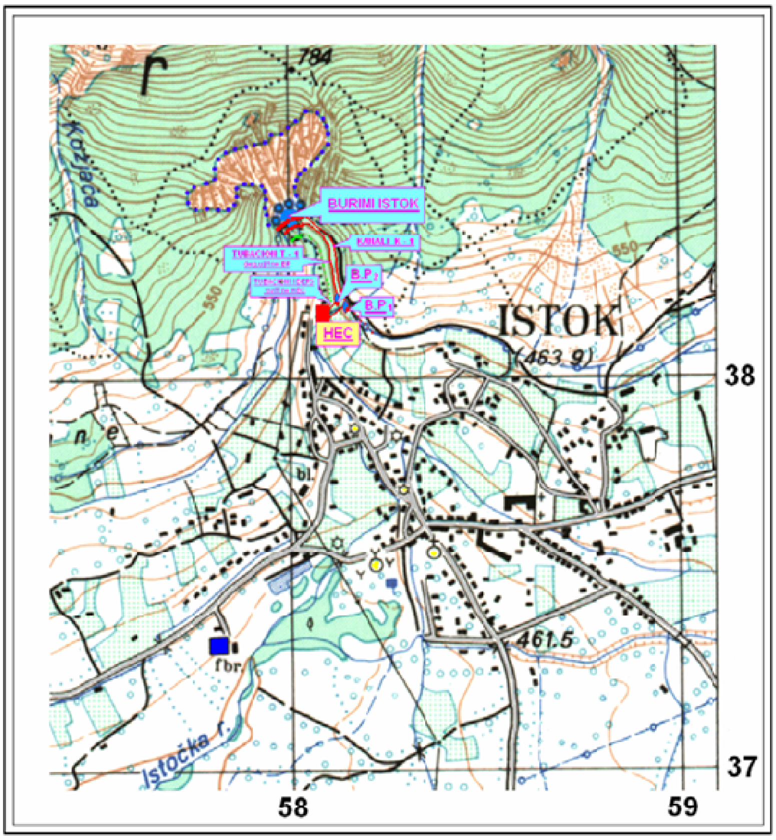


Fig. 17 Location of the hydropower plant.

m and the pipeline of water delivery to P.B. 3 basin is at 498-497 m quota. The HPP building is situated at an altitude of 474 m and is about 4.00 m above the river valley.

5. Environmental Impact, Assessments and Counteraction Measures

5.1 Structures and Roads

There were no river deviations during the works which do not affect the valley ecology.

Roads are not affected in this project. During construction and reconstruction, the facilities of other sectors, agriculture, water supply and the fish (trout) farming plant are not affected at all, which inflow water from the HPP water outflow channel. Making the HPP again operational would have a positive effect on the Istog area and beyond because the source is simultaneously fully utilized, electricity is produced and a significant number of workers are employed.

5.2 Visual Effect

The visual effect is not affected (Fig. 18) and the reason is that there are many constituent compositions that will be reconstructed with the exception of the second instance that will be a new composition. The solution of pipeline water inflow to the pressure basin has been recognized in order to maintain the visual effect.

5.3 Flora and Fauna

Situated in a mountainous area, flora and fauna are the most developed elements both throughout the river valley and forest slopes.

5.4 Land Use

Lands in the Istog river valley are in good physical conditions, cultivated in all surfaces, systemized, equipped with all necessary irrigation and drainage systems.

Fig. 18 Visual effect.

5.5 Population and Employment

The town of Istog with its surroundings has a relatively small population of 10,000 inhabitants. Employment and labor market is limited because the town of Istog has a limited physical position.

Restoring the HPP, fishing and the development of agriculture, these sectors reduce the unemployment level and raise the living standards.

6. Conclusions and Recommendations

From the conducted study, it can be concluded as:

- The results achieved from this study support the general trend in the world to reach a better understanding towards better and complex use of renewable resources. Water resources management is an iterative process of integrated decision-making regarding the uses and modifications of waters and related lands within a geographic region [8];
- Although Kosovo, compared to the neighbor countries, is poor in water resources (hence hydropower resources), it is an urgent task starting and conducting studies as soon as possible on all streams, progressively drafting a master plan in now new conditions, treating water as a vital element in order to avoid emerging crisis in the near future;
- With the presented solutions (without affecting their components of water economy: on water supply of the population, agriculture, fish economy, valley ecology), the Istog source may provide an average annual electricity production of nearly 7 million kWh with a gross income of about 300,000 euro per year;
- The implementation of this study is extremely easily realized for a very short term;
- It is recommended to colleagues who are in various stages of their doctorate to be involved in similar studies for other water sources, specifically contributing to gradually complete an overview of water and hydropower opportunities of the state of Kosovo. To this regard, the department, faculty in cooperation with relevant local government ministries have a real opportunity to contribute to this nature;
- Authors of this study is aware that his work has flaws but it is a step in the right direction in paving the road for conducting concrete studies and serving Kosovo's economy, creating a foundation where following works will be more profoundly performed from a scientific standpoint.

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Estimation of Soil Hydrodynamic Parameters Related to Agricultural Practices—Case of the Tougou Experimental Site (Burkina Faso)

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Abstract: This study aims to estimate the hydrodynamic properties of soils under various agricultural practices in the Tougou catchment in northern Burkina Faso. The methodology adopted is based on the determination of the unsaturated hydraulic conductivity and capillary sorptivity close to saturation. This method relies on the measurement of the transient infiltration flux at the soil surface with imposed hydraulic head varying from -60 to -20 mm. These tests are carried out on control, stony line, half-moon and zai plots. The results show a difference in hydrodynamic parameters according to the agricultural practices. The unsaturated hydraulic conductivity is 33.1 cm/h, 13.1 cm/h, 20.3 cm/h and 4.0 cm/h for zai, control, stony line and half-moon plots respectively. The unsaturated hydraulic conductivity is 33.1 cm/h, 13.1 cm/h, 20.3 cm/h and 4.0 cm/h for zai, control, stony line and half-moon plots respectively. The pores participating to water transfer also differ. The mean size of drainable pores is 43.7, 56.2, 22.3 and 87.2 µm on control, stony line, half-moon and zai plots respectively.

Key words: Agricultural practice, unsaturated hydraulic conductivity, sorptivity, soil, Tougou, Burkina Faso.

1. Introduction

The Sahel of Burkina Faso, like all the Sahelian regions, undergoes for several decades various phenomena of natural and anthropogenic degradation of ecosystems. This degradation, accentuated by a decrease in rainfall over the last decades, causes a modification of the processes and mechanisms that govern these ecological units, which ultimately leads to a modification of the state and aspect of these ecosystems. The various anthropogenic actions combined with the rainfall deficit, cause a reduction of the vegetal cover, or even locally its disappearance. Indeed, in areas where vegetation has disappeared, it has developed on soil surface an indurated, continuous and impermeable layer (superficial crust). This layer set up is controlled by the action of the kinetic energy of rainfall (splash effect) and runoff. It thus appears at landscape scale an imbalance in the spatial distribution of water, accentuating the constraining nature of this resource. To this, added anthropic pressures and the development of livestock farming thus increasing the vulnerability of the environment to drought [1].

The degradation of natural resources experienced by Sahelian countries in recent years limit their capacity for endogenous development. To increase their resilience to this, Sahelian farmers in Burkina Faso have adopted several agricultural practices for the water mobilization at the farm scale [2-7]. These practices, which appeared between 1980 and 1985 and are very demanding in terms of working time and physical effort, nevertheless constitute innovative alternatives for the development of a resilient agriculture in the Sahel. They consist of applying agricultural practices such as zai, half-moon and stony line and using of short cycle varieties. These

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techniques have allowed not only the restoration of many uncultivated lands [8], but also the improvement of cereal yields [9] and the increase of the groundwater level [10]. Fatondji, D., et al [8] reported that with the zai technique 100,000 to 300,000 ha of degraded land were rehabilitated in Burkina Faso while Roose, E., et al. [9] showed in the same country that under zai, sorghum yields are multiplied by about 1.6. These yield increases result from the combined effect of water retention, composting and supplemental manure fertilization.

In such context, knowledge of soil water transfer processes is a key priority. Thus, the present study is implemented on an experimental site in Tougou located in the north of Burkina Faso. It aims at estimating soil hydrodynamic properties related to several types of agricultural practices.

2. Material and Methods

2.1. Study Area

The study area is the Tougou catchment (between Latitudes of 13°40’ N, and longitudes of 2°13’ W), a surface sub-catchment of Nakambe river in the north-east of Burkina Faso. It has a surface area of 37 km² (Fig. 1). The climate is semi-arid with a mean annual rainfall varying from 400 to 650 mm. Temperatures range between 18 and 40 °C. The dry season extends from October to May and the rainy season from June to September with peak precipitation generally recorded in July or August. Soils are cultivated or denuded (degraded) and the vegetation consists of savanna, shrub and grassy steppe.

The experimental design (Fig. 2) consists of two separate Fisher blocks A and B, the distribution of which is random. Each block consists of four plots of 200 m^2 (20 m long by 10 m wide) each receiving a specific treatment: direct seeding as a control plot (T0), a stony line plot (T1), a half-moon plot (T2) and a zai plot (T3). Zai (plot T3) is a complex system of restoring the productivity of degraded soils, a particular type of an open hole (20-40 cm in diameter and 10-15 cm deep), concentrating runoff and organic matter. The

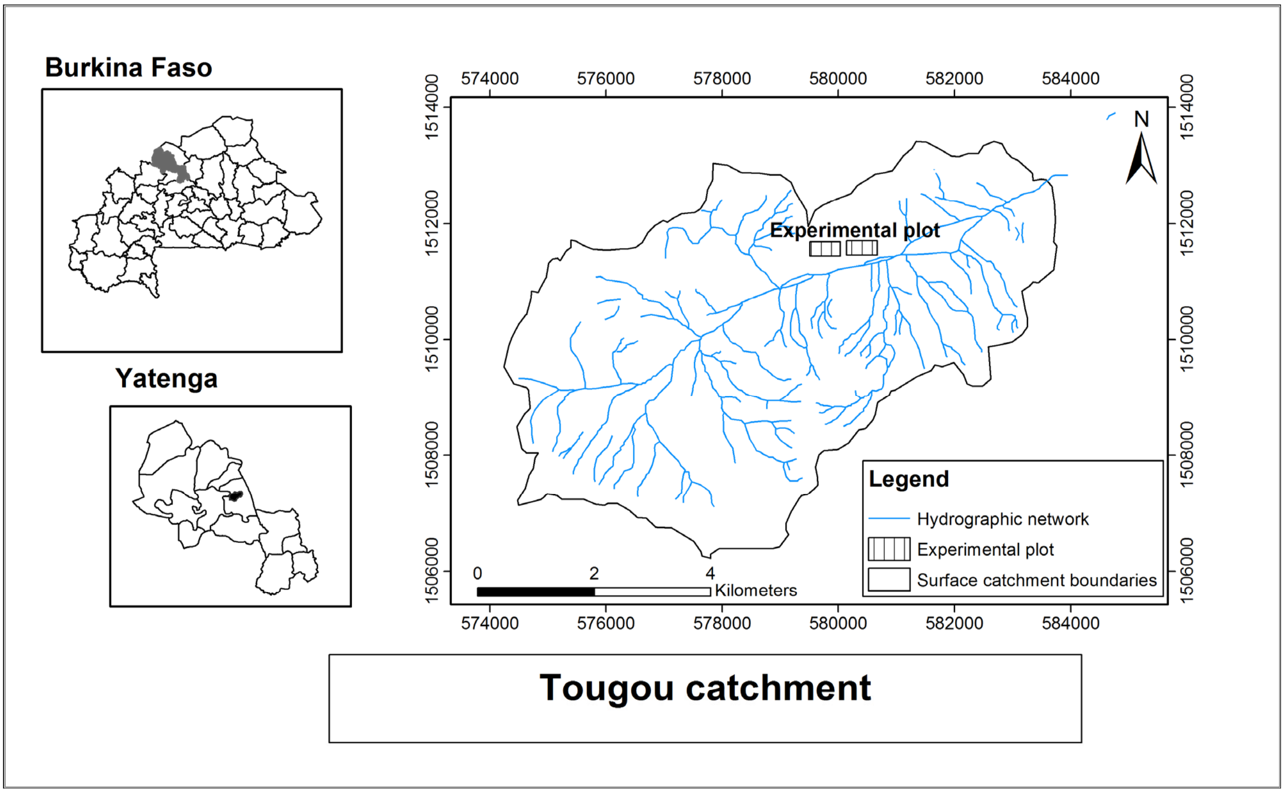

Fig. 1 Location of Tougou surface catchment.

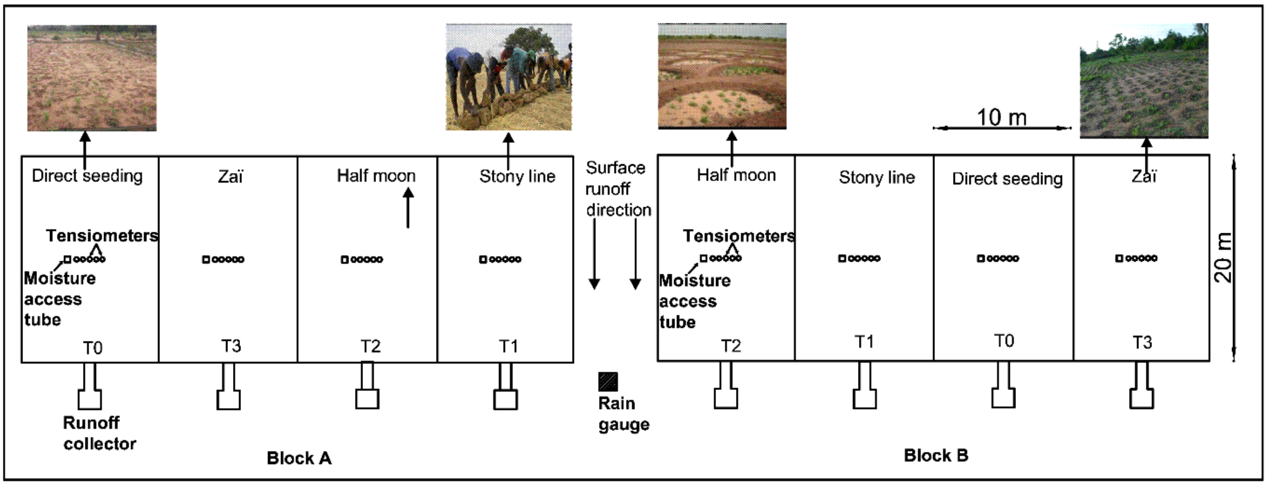

Fig. 2 Design of agricultural practices plots in Tougou experimental site.

spacing between the zai holes is 60 cm × 60 cm. The stony lines (plot T1) are constructed as a hydraulic barrier of polyform stones anchored 15 cm deep and located 15 m from plot upstream limit, parallel to the contour lines to dissipate surface runoff energy. Half-moons (plot T2) are semicircular holes of 4 m in diameter and 15 to 25 cm deep, and are excavated perpendicular to water flow direction. The spacing between half-moons is 2 m. The control plot (T0) is a direct seeding, in rows, as practiced in the locality. The spacing between seedlings on the control, stony-line and half-moons plots is 50 cm × 50 cm. An organic amendment (cow dung) of 5t/ha is applied to each plot prior to seeding and a microdose application of NPK (Nitrogen, Phosphorus, Potassium) fertilizer (2-4g per hole) after crop emergence and urea (1 g per hole) at the run [11, 12]. Plots are grown with a 70 days cycle millet variety (Kiipalla). The choice of this variety is justified by its precocity, its resistance to drought and its wide adoption by local farmers.

2.2 Field Data Collection

Measurements of the unsaturated hydraulic conductivity are implemented using disc infiltrometer on all eight plots of the experimental site. On each plot, the infiltrometry tests are carried out at suctions 20, 40 and 60 mm with a repetition of 3 measurements per suction and the average value was recorded. Before starting and ending each test, soil samples are analyzed in order to estimate the initial and final water contents.

2.3 Data Processing

2.3.1 Unsaturated Hydraulic Conductivity and Capillary Sorptivity

The three-dimensional cumulative infiltration per unit of area, I (mm) for the entire time range, can be expressed by Eq. (1) [13].

$$\frac{2(K_0-K_n)^2}{S_0^2}t = \frac{2}{1-\beta}\frac{K_0-K_n}{S_0^2}\left\{I_{3D}-K_nt\left[\frac{\gamma S_0^2}{R_D(\theta_0-\theta_n)}\right]t\right\} - \frac{1}{1-\beta}ln\left\{\left\{exp\left[\frac{2\beta(K_0-K_n)}{S_0^2}\right]\left[I_{3D}-K_nt - \left(\frac{\gamma S_0^2}{R_D(\theta_0-\theta_n)}\right)t\right]+\beta-1\beta\right\}\beta^{-1}\right\} \quad (1)$$

where R_D (m) is the radius of the disc; θ_0 and θ_n are the final and initial volumetric water content ($m^3 \cdot m^{-3}$), respectively; S_0 is the sorptivity ($m \cdot s^{-0.5}$) for θ_0; and γ is the proportionality constant, the value of which can be approximated to 0.75 [14]; K_0 and K_n are the soil hydraulic conductivity values ($m \cdot s^{-1}$) corresponding to θ_0 and θ_n, respectively; and β is a shape constant that commonly takes an average value of 0.6 [14]. In spite of its relative complexity, Eq. (1) is valid for the entire time range, from $t = 0$ to $t = \infty$. However, taking into account that infiltrometer experiments do not require very long time ranges of application, Haverkamp, R., et al. [13] established that, for short to medium time and assuming $K_n \approx 0$, Eq. (1) can be simplified to

$$I_{3D}=C_1\sqrt{t}+C_2 t \quad (2)$$

Where

$$C_1 = S_0 \quad (3)$$

$$C_2 = \frac{2-\beta}{3}K + \frac{\gamma S_0^2}{R_{D(\theta_n-\theta_0)}} \quad (4)$$

Using this expression, Vandervaere, J., et al. [15] proposed the differentiated linearization method to infer soil hydraulic properties using linear regressions. The technique consists in differentiating Eq. (2) with respect to the square root of time.

$$\frac{dI}{d\sqrt{t}} = C_1 + 2C_2\sqrt{t} \quad (5)$$

And next plotting the $\frac{dI}{d\sqrt{t}}$ term as a function of $\sqrt{t}$. The C1 is the intercept and C2 is the slope of the corresponding regression lines. According to the authors, the differentiated linearization technique allowed visual monitoring of the contact layer, when used, eliminating its influence on the estimates of the soil hydraulic properties.

2.3.2 Mean Size of Drainable Pores

The knowledge of the capillary sorptivity S0 and of the hydraulic conductivity K has been used by some authors [16, 17] to define the capillary length λc which is a macroscopic scale expressing the relative importance of the capillary and gravitational forces acting on water penetration in the soil. Its mathematical formulation is as Eq. (6):

$$\lambda_c = \frac{bS_0^2}{(\theta_n - \theta_0)K} \quad (6)$$

Where b is 0.55, a value generally accepted for most soils [18]. Using the elementary laws of capillarity, Philip, J. R. [16] introduced the mean size drainable pores, λ_m, given by Eq. (7):

$$\lambda_m = \frac{\sigma}{\rho_w g_{\lambda_c}} \quad (7)$$

Where σ is the surface tension coefficient of water (0.072 N/m at 25 °C), ρ_w the density of water (1,000 Kg/m^3) and g the acceleration of gravity (9.81 m^2/s). By introducing in Eq. (6), the numerical values of σ, ρ_w and g are obtained by expressing λ_m in μm Eq. (8):

$$\lambda_m = 13.3\frac{(\theta_n - \theta_0)K}{S_0^2} \quad (7)$$

3. Results and Discussion

3.1 Results

3.1.1. Unsaturated Hydraulic Conductivity and Capillary Sorptivity

The unsaturated hydraulic conductivity and the capillary sorptivity according the suction follow a logarithmic law and change in a decreasing manner when the suction increases on all the plots. As an illustration, the evolution on the plot T3A of these two parameters as a function of the suction is represented in Fig. 3.

On each of the two blocks of the experimental site, the highest unsaturated hydraulic conductivity values (Table 1) are found in the zai plots and the low values in the control plots. With regard to the sorptivity values, the half-moon plots show the highest values whereas the zai plots show the lowest values.

3.1.2. Mean Size of Drainable Pores

The distribution of mean size of pore as a function of agricultural practices (Fig. 4) indicates that the maximum of pores participating to the flow is recorded on zai plots. This is totally in agreement with the results obtained for the unsaturated hydraulic conductivity. This is certainly due to the amendment in organic matter made on this practice which allows increasing the microbiological activity of the soil. The latter tends to favor the creation of a preferential flow path for water in the soil, hence the importance of the infiltration capacity of this practice.

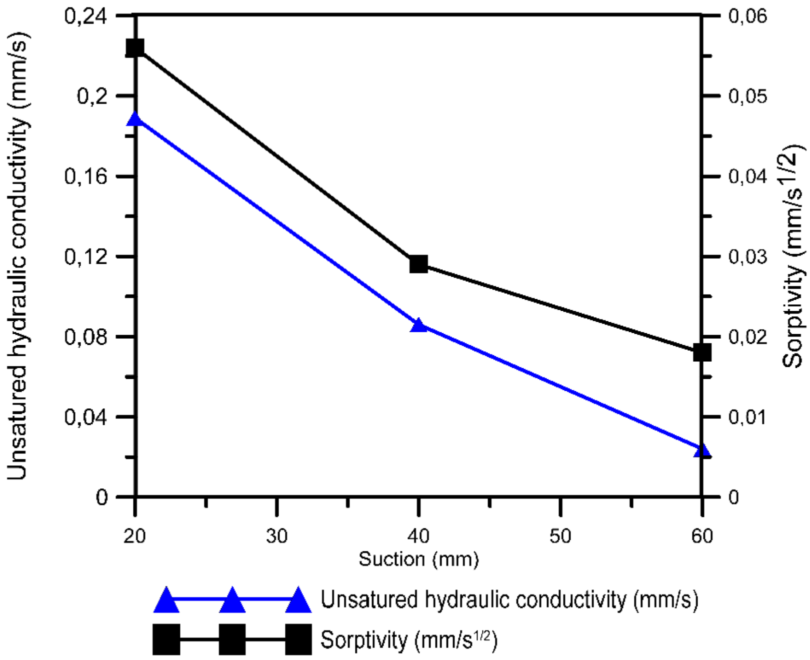

Fig. 3 Distribution according to the suction of unsaturated hydraulic conductivity and capillary sorptivity on plot T3.

Table 1 Unsaturated hydraulic conductivity (K) and capillary sorptivity capillaire (S_0) recorded at a suction 40 mm.

Plot	K (mm/s)	S_0 (mm/s$^{1/2}$)
T0A	0.031 ± 0.008[a]	0.052 ± 0.003[b]
T1A	0.048 ± 0.005	0.042 ± 0.008
T2A	0.009 ± 0.001	0.067 ± 0.010
T3A	0.086 ± 0.012	0.029 ± 0.002
T0B	0.042 ± 0.008	0.040 ± 0.005
T1B	0.065 ± 0.010	0.034 ± 0.006
T2B	0.013 ± 0.0002	0.044 ± 0.004
T3B	0.098 ± 0.012	0.021 ± 0.005

a: Variation coefficient for hydraulic conductivity; b: Variation coefficient for capillairy sorptivity.

3.2 Discussion

The infiltrometry tests demonstrate that unsaturated hydraulic conductivity and sorptivity decrease with increasing suction. Indeed, these two parameters which follow a logarithmic law, vary with soil water content and the suction. At suctions close to saturation, the movement of water is controlled by the coarsest macroporosity. The soil has a high hydraulic conductivity associated with high porosity. As the soil becomes unsaturated, the larger pores are emptied and the flow occurs in smaller and smaller pores with more and more tortuous flow paths. These results confirm a pronounced differentiation of these soils according to the agricultural practice with the consequence of an accentuation of the spatial discontinuity, as well from surface roughness as of their hydraulic behavior. In addition to highlighting this diversity of surface conditions, the analysis of the results obtained with regard to the hydraulic properties of the surface reveals a strong variation of the infiltration capacity. The highest values are found on the zai plots while the lowest values are found on the control plots. These differences are undoubtedly attributable to the reorganization of land cover by the implementation of the agricultural practices because a modification of the

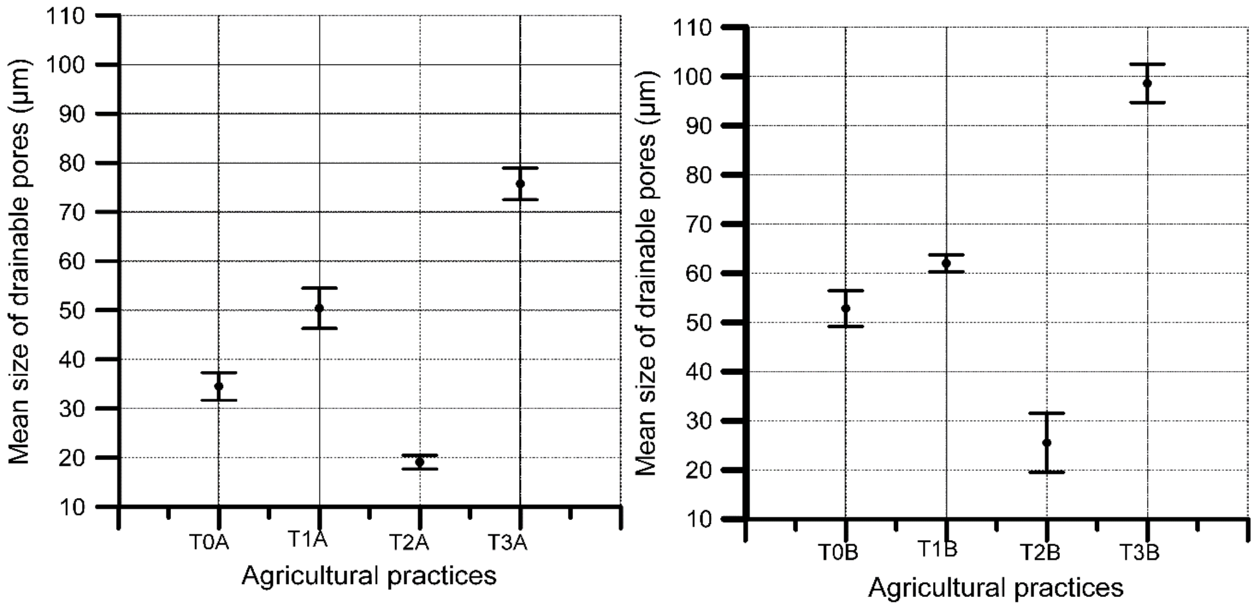

Fig. 4 Distribution according to agricultural practices of mean size of drainable pores.

organization of the poral system of the superficial horizons leads to a reduction of the hydraulic conductivity close to saturation [15, 19, 20]. The hydraulic conductivity values estimated on the control plots correspond to those found on degraded soils. It reflects the hydrodynamic behavior of soils consisting generally of glacis having a superficial layer characterized by a low infiltration capacity due to a reduced porosity, which appears this laminate coating to a real hydraulic barrier which strongly limits the water inflow in the soil. This type of land cover generates large runoff and correlatively leads to a very low accumulation of water in the soil. The hydraulic conductivity values estimated on the zai and stony line are larger than those of the control plot. Both of these agricultural practices tend to improve the infiltration capacity of the soil. For zai, the destruction of the upper soil layer will favor the capture of runoff, its solid and soluble load, and tends to increase the infiltration capacity [21]. This leads to high hydraulic conductivity values resulting from the improvement of the soil roughness. Indeed, runoff management, manure conservation and the concentration of nutrients will create conditions for optimum water transfer in the soil through the generation of preferential flow paths (high termite activity). Concerning the stony line plots, improvements in hydrodynamic parameters are not very significant compared to the control plot in that the experimental design is in its second year of existence and several studies [22, 23] carried out in this region of Burkina Faso showed that such practice becomes efficient after three years. The results obtained on the half-moon show very low values compared to those of the control plot. This is certainly due to the fact that this agricultural practice tends to carry a lot of suspended matter which during the settling phase will clog the soil thus making the infiltration capacity very weak. The comparison of infiltrometry tests show that unsaturated hydraulic conductivity and sorptivity do not always change in the same way. In fact, the decrease of the hydraulic conductivity is much faster than that of the sorptivity. This behavior is due to several factors among which one can mention the presence of a vesicular porosity which reduces the capacity of infiltration. This vesicular porosity appears following the rains and is formed by trapping air during heavy rainfall. Indeed, some authors [24] have shown that in arid zone, the hydrodynamic characteristics of superficial microhorizons could be affected by the appearance of these vesicles. This vesicular porosity is linked to the existence of an underlying microhorizon with low porosity, most often a material with low gas diffusivity [24]. This results in a reduced hydraulic conductivity of the superficial organizations. However, several authors have shown that in the Sahelian zone, it is the hydrodynamic characteristics of superficial microhorizons which condition, to a large extent, the infiltrability of the whole soil. It is therefore possible to consider the presence of these vesicles close to the surface as an index of low permeability [24] because the statistical analysis shows a very good relationship between the abundance of these pores and the runoff ability [25].

Numerous field or laboratory studies on undisturbed soils have shown a very significant increase in hydraulic conductivity close to saturation. This increase is generally greater than that expected from an exponential relationship of K (h), a relationship often verified in soil physics for remolded soils or with a particularly homogeneous structure [26]. Jarvis, N. J. and Messing, I. [27] have shown that, for several soils, this increase was particularly marked for water heads greater than -60 mm, i.e. when pores of equivalent radius greater than 0.25 mm participate to the flow. These authors attribute these observations to the effect of soil macroporosity, defined as the set of pores with an equivalent radius greater than 0.25 mm (thus visible to the naked eye) participating to water transfer.

4. Conclusion

This study revealed that unsaturated hydraulic conductivity and sorptivity decrease with increasing suction. The hydrodynamic behavior of the soils under agricultural practices reveals a strong variation of the infiltration capacity. The highest values are found on the zai plots while the lowest values are found on the control plots. The unsaturated hydraulic conductivity is 33.1 cm/h, 13.1 cm/h, 20.3 cm/h and 4.0 cm/h for zai, control, stony line and half-moon plots respectively. The pores participating to water transfer also differ. The mean size of drainable pores is 43.7, 56.2, 22.3 and 87.2 μm on control, stony line, half-moon and zai plots respectively.

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