THE INFLUENCE OF SOIL TILLAGE SYSTEMS ON BULK DENSITY IN THE BRAILA ISLAND

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Abstract

The paper analyzes the influence of three soil tillage systems: conventional (CT), minimum tillage (MT), and no-tillage (NT) on bulk density values, under the specific conditions of alluvial soils in the Great Island of Brăila, an area with unique soil characteristics, characterized by high textural variability and a marked degree of heterogeneity. The study was based on a field experiment in which soil samples were collected from four depths (0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm) at two key moments: three days after sowing and immediately after harvesting. The samples were analyzed in the laboratory according to the Canarache method (1991), and the bulk density values were correlated with the tillage system applied. The results showed a progressive increase in bulk density with depth. At sowing, the lowest values were recorded in MT (1.09 g/cm³), and at harvest, NT recorded the highest values (1.22 g/cm³) at a depth of 0–10 cm. However, all values determined were below the critical threshold of 1.4 g/cm³, indicating that none of the systems led to compaction harmful to root development. Statistical analysis (ANOVA) showed no significant differences between the tillage systems. The study confirms that the application of conservative systems does not adversely affect the physical structure of the soil and can be a viable alternative for the sustainable management of alluvial soils, while also offering stable and high agronomic potential.

Keywords: bulk density, working systems, conservation agriculture, alluvial soils, compaction

Soil cultivation using various farming techniques causes changes in its physical properties to a greater or lesser extent. This, in turn, affects crop development and, consequently, production results. In this regard, it is highly recommended to analyze the interaction between soil cultivation systems and the physical properties of the soil.

Soil preparation has always been the starting point for the idea of high-performance agriculture throughout history (Busari M.A. *et al*, 2015). The main soil tillage system that has generated the greatest advances in production has been the conventional system (CT). The value of CT was due to its good weed control capacity, combined with a significant increase in production results (Ashapure A. *et al*, 2019). Subsequently, as a result of the evolution of soil tillage systems, both under the pressure of climatic constraints and the desire to conserve the pedosphere, conservative systems were developed (Mihu G.-D. *et al*., 2022). These include minimum tillage (MT), i.e., cultivation techniques involving shallow soil mobilization, and direct seeding techniques, known as no-tillage (NT) (Giller K.E. *et al*., 2015). The main difference between conventional and conservation technologies is that there is no plowing (Cakpo S.S. *et al*., 2025). Furthermore, in the conservative system, the presence of plant residues on the soil surface is essential, taking the form of mulch, in a minimum percentage of 30% (Jităreanu G. *et al*, 2020).

In contrast to the conventional system, both minimum tillage and no-tillage have become increasingly interesting due to the reduction in diesel consumption, equipment wear, and labor requirements (Calistru A.E. *et al*., 2024). Furthermore, conservative systems offer real advantages in terms of soil physical properties (structure, porosity, water infiltration rate, hydraulic conductivity), thus promoting a high degree of sustainability and increased productivity (Villamil B.M. *et al*, 2015; Zhao X. *et al*, 2017).

In terms of aggregate size and stability, the direct seeding system favoured the formation of an exponentially higher number of macroaggregates,

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with superior water stability compared to those in CT (Mihu G.-D. *et al*. 2022). The percentage difference between the water-stable aggregates present in NT and CT was 36% in favor of the conservation system. Interestingly, compared to the BD values, influences also appear here with increasing time allocated to the experiment, but they are significantly higher. In the case of long-term experiments, over 10 years, the differences increased by 38.7%-69.2% in favor of the NT system (Blanco C.H. *et al*, 2009).

What is certain is that the sum of the studies analyzed concludes that regardless of the adoption period, regardless of rainfall or rotation, conservative systems favor a significant increase in the percentage of water-stable aggregates as well as macroaggregates. Continuing this line of thought, many studies indicate a 50% increase in large aggregates and a 32% increase in water-stable aggregates. The mechanisms behind this differentiation in soil formations are easy to identify as they represent the very essence of conservative systems (Mihu G.-D. *et al*., 2025). The first essential aspect for the occurrence of these transformations in the soil is the retention of plant residues, in a proportion that varies according to the chosen soil tillage system, but also the reduction of interaction with the soil, thus favouring the accumulation of organic matter in the upper part of the soil profile (Schmidt E.S. *et al*, 2018, Țopa D.-C. *et al*., 2025). Based on these changes, the aggregates are less wetted, considerably reducing the risk of destructuring (Blanco C.H. *et al*, 2018).

As the size of the aggregates and their water stability increase, the concentration of carbon in the soil also increases. The amount of organic carbon present in the conservation system is 10-29% higher than in the conventional system (Li Y. *et al*, 2019). Furthermore, by increasing the percentage of plant residues on the soil surface, there is also an increase in the population of soil microorganisms, which directly favors aggregation processes, practically supporting the formation of water-stable and large aggregates (Li Y. *et al*, 2018).

The aim of this study is to evaluate the influence of different soil tillage systems: conventional (CT), minimum tillage (MT), and no-tillage (NT) on bulk density values under the specific conditions of alluvial soils on the Insula Mare a Brăilei. This analysis contributes to identifying the most efficient soil tillage technologies from the perspective of preserving the physical structure and productive potential of the pedosphere.

To achieve this goal, the following specific objectives were set:

- determination of bulk density values for each soil tillage system at four profile depths (0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm) at two distinct times: before sowing and after harvest;
- comparative analysis of the variation in bulk density between conventional and conservation systems, in order to highlight possible differences in soil compaction during the growing season;
- highlighting the effects of conservation systems (MT and NT) on maintaining or improving the physical properties of alluvial soils, with an emphasis on porosity and water retention potential.
- identifying trends in bulk density depending on the type of work applied and the sampling depth, in order to assess the risks of compaction in the active soil layer.

Thus, the implementation of sustainable soil management systems can contribute significantly to maintaining the physical properties of the soil, preventing compaction, and optimizing conditions for the development of the plant root system. This paper aims to make a significant contribution in this regard by comparing the influence of conventional and conservation systems on soil bulk density, a key indicator in assessing the health of the pedosphere.

MATERIAL AND METHOD

The embanked area of Insula Mare a Brăilei is a territory that has undergone extensive land improvement works. Until this process began, the area in question was known as “Balta Brăilei.” The area occupied by this formation was approximately 99,000 hectares, bordered by the Danube and the Măcin branch. The island that was formed has an elongated shape and an impressive surface area, thanks to its length of approximately 65 kilometers and its width of between 12 and 16 kilometers (Titianu L., 2010).

The soil is underdeveloped, young, and constantly evolving, formed mainly by alluvial deposits. The Danube has exerted a series of highly intense actions, thus generating erosion, transport, and deposition of sediments. The Brăila Marsh, being a floodplain, is characterised by a low, flat relief. Due to the fact that its formation depended on how various alluvium were brought and deposited, there is a high degree of heterogeneity, both in terms of grain size and chemical composition. A more detailed analysis of the soil reveals areas characterized by coarse texture, in contrast to other areas with a clayey texture, and obviously areas with intermediate texture. The textural unevenness of the alluvial deposits differs both horizontally and vertically. As will be seen from the soil profile analysis, variations in texture occur with depth at the same location. Due to the fact that, until it was embanked, the island experienced annual periods of flooding and water retreat, the process of soil formation, and therefore humus accumulation, was hampered by the constant accumulation of new, raw sediments on top of the previous sediments. A characteristic of the soil formation of this type of land is that the soil tends to transform and acquire the characteristics of the genetic soil types already present in the area (Anup K.U. and Kalu S., 2015).

In order to collect soil samples for the analysis of bulk density values, two sampling periods were taken into account. Therefore, samples were taken shortly after sowing (3 days) and immediately after harvesting. In order to reflect the reality of the situation in the field as accurately as possible, the samples were taken from unmoved, uniform soil surfaces, in no case from tractor wheel tracks, and were selected at random. In addition, three sampling points were selected for each soil tillage system analyzed (CT, MT, NT), at a minimum distance of 10 meters from the access roads to the field.

Soil samples were collected in cylinders with a volume of approximately 100 cm^3 with the edges cut at an angle of approximately 150. Each point associated with each soil tillage system had four sampling depths: 0-10, 10-20, 20-30, and 30-40 cm. Special attention was paid to sample collection by removing plant debris from the surface of the sampling point so as not to distort the results. At the same time, an attempt was made to reduce sample handling in order not to degrade the structure of the soil sampled. After harvesting, the samples were taken to the laboratory, where they were dried in an oven (105°C), and in order to determine the bulk density values for each working system, the formula proposed by Canarache was used, as it is considered one of the most effective for establishing these values (1991).

RESULTS AND DISCUSSIONS

The Great Island of Brăila is an area of land with unique characteristics compared to the rest of the soil found in Brăila County. As a result of the embankment process, the land within the enclosure has become agricultural. The land was formed by the gradual but constant accumulation of various quantities of water-borne sediments. The Danube has thus managed to shape and reshape the soil over time, giving it a fairly high degree of variability. Therefore, the land within the embanked area is classified as alluvial soil, which explains the high degree of variability in its physical properties, even over short distances.

At the first depth interval, at sowing, the lowest value is found in MT, with 1.09 g/cm³, followed by CT with 1.11 g/cm³ and NT with 1.12 g/cm³. Although there are differences between soil tillage systems, we can say with certainty that the differences are minor and that conservative systems do not hinder plant development. At a depth of 10-20 cm, the values increase exponentially, with the MT system, which previously had the lowest value, reaching the highest level, 1.30 g/cm³, followed by NT with 1.29 g/cm³ and CT with 1.26 g/cm³. Again, the data are very close to each other, the difference being negligible. At the third depth interval, 20-30 cm, the NT and MT values are similar, approximately 1.30 g/cm³, and CT is 1.29 g/cm³, and we can say that the tendency to show very small differences continues. For a depth of 30-40 cm, MT has the highest bulk density values, at 1.31 g/cm³, followed closely by NT at 1.30 g/cm³. However, there are greater differences between the conservative systems and the conventional system, with CT having a value of 1.26 g/cm³.

Harvest data indicate an increase in bulk density values, most evident at a depth of 0-10 cm, where NT reaches 1.22 g/cm³, followed by MT and CT with 1.19 g/cm³ and 1.18 g/cm³. Therefore, during the growing season, NT generated greater soil compaction than MT and CT, although the differences between the systems are not very large. At a depth of 10-20 cm, the hierarchical trend continues, with the highest values being found in NT, 1.34 g/cm³ compared to 1.30 and 1.31 g/cm³. At a depth of 20-30 cm, the NT and MT values are slightly lower than in the previous interval, at 1.33 g/cm³ and 1.30 g/cm³, respectively. The CT system this time shows a value similar to MT, also at 1.30 g/cm³. For the last depth range, 30-40 cm, the CT system maintains its value of 1.30 g/cm³, but we find increases in both NT and MT, both reaching 1.34 g/cm (Table 1).

We can observe fairly small differences in bulk density between the three systems analyzed. Furthermore, the values obtained across all depth intervals are not likely to cause problems for root system development. In this regard, we can conclude that, in this case, conservative systems will not harm crops in terms of this indicator.

Table 1

Bulk soil density values from the experiment

Depth	NT sowing	CT sowing	MT sowing	NT harvesting	CT harvesting	MT harvesting
0-10 cm	**1.12** **-0.06a**	1.11 -0.08a	1.09 -0.05a	**1.22** **+0.04a**	1.18 -0.01a	1.19 +0.05a
10-20 cm	**1.29** **+0.03a**	1.26 -0.06b	1.30 -0.02a	**1.34** **+0.08a**	1.30 -0.02b	1.31 -0.01a
20-30 cm	**1.30** **+0.01ab**	1.29 -0.04a	1.30 -0.01ab	**1.33** **+0.04b**	1.30 -0.03a	1.30 -0.01ab
30-40 cm	**1.30** **-0.01a**	1.26 -0.05a	1.31 -0.01a	**1.34** **+0.04a**	1.30 -0.01a	1.34 +0.02a

Note: NT – no-tillage system; CT – conventional tillage system; MT – minimum tillage system. Data are presented as mean ± standard error (n = 10). Within each column, values followed by the same lowercase letters are not significantly different, while values followed by different lowercase letters are significantly different (Tukey's test, $p \leq 0.05$).

Statistically, the data obtained this year indicate the following (Figure 1).

At a depth of 0-10 cm, in NT, the SD and SE values are 0.0916 and 0.0458, which is a low level of data variability and also associated with a high accuracy of the mean estimate.

In the CT system, the standard deviation and standard error values were lower than in NT, at 0.0534 and 0.0267. Therefore, data variability is lower and the accuracy of the mean estimate is higher.

For MT, we find the lowest values of standard deviation and standard error, and automatically, the most concentrated values of data distribution and the most accurate mean estimation, with the resulting data being 0.0428 and 0.0215.

The F and p values of 0.772 and 0.505 indicate the absence of significant differences in soil tillage systems.

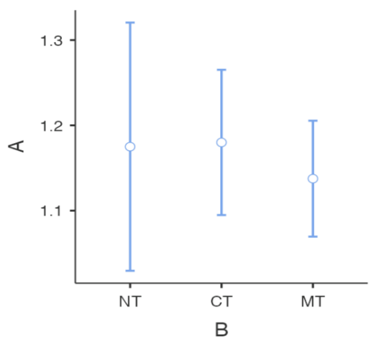

Figure 1 **Variability of specific data for bulk density at 0-10 cm., 2024**

For the depth range of 10-20 centimeters, based on ANOVA analysis, we can observe the following aspects (Figure 2):

In the NT system, the SD and SE values of 0.1284 and 0.0643 indicate the presence of data close to the mean and a low standard error level.

The CT system has a lower level of data variability and a higher accuracy of mean estimation, with values of 0.0828 for SD and 0.0413 for SE.

The MT system has the highest degree of data variability, with an SD of 0.1328.

In terms of standard error, this is not high, but it exceeds the results of the other two analyses (0.0664).

The F and p values of 0.340 and 0.725 indicate the absence of significant variability between the soil tillage systems, compared to the variability found within each analyzed system.

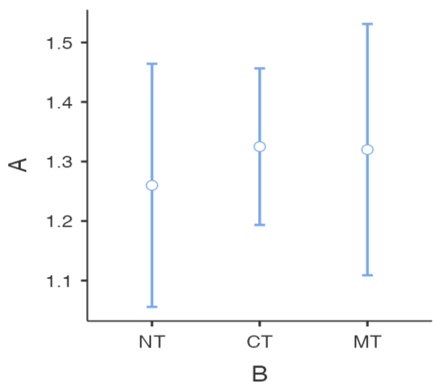

Figura 2 **Variability of specific data for bulk density at 10-20 cm., 2024**

For depths of 20-30 cm, ANOVA data indicate the following characteristics (Figure 3):

At the NT system level, we find a low degree of variability, associated with a fairly high precision of the mean, with SD and SE values of 0.1454 and 0.0727.

For the CT system, we note the most concentrated values within the group, as well as the most accurate estimate of the data mean, with 0.0773 and 0.0388 SD and SE.

In the case of MT, we find intermediate values, compared to CT and NT, for SD and SE, with 0.1311 and 0.0656.

The F and p values, 0.109 and 0.898, show no significant differences between the systems.

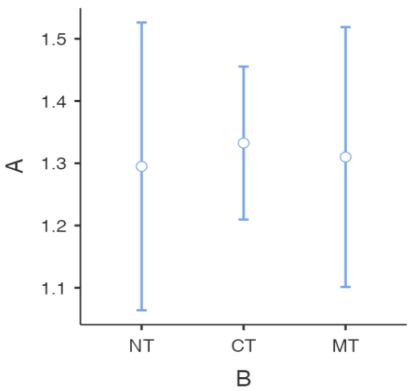

Figure 3. **Variability of specific data for bulk density at 20-30 cm., 2024**

At the last depth level, 30-40 cm, the statistical results are as follows (Figure 4):

In the direct sowing system, we have SD and SE values of 0.1437 and 0.0717, thus a low data variability and a low standard error in terms of mean estimation.

In the CT system, we find the most concentrated values and the most accurate estimate of the mean, with SD and SE values of 0.0501 and 0.0251.

The last system, MT, with its SD and SE values, has an intermediate level compared to NT and CT, with results of 0.1208 and 0.0602.

The F and p values of 0.0254 and 0.975 indicate the absence of significant differences between the analyzed groups.

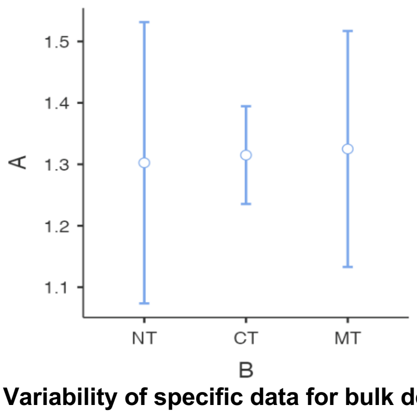

Figure 4 **Variability of specific data for bulk density at 30-40 cm, 2024**

The bulk density values were: 1.08 g/cm³ (0-10 cm), 1.29 g/cm³ (10-20 cm), 1.32 g/cm³ (20-30 cm), and 1.33 g/cm³ (30-40 cm). Based on these results, we can conclude that the tilled soil does not have a high degree of compaction. For the 0-10 cm interval, the value of 1.08 g/cm³ indicates the presence of soil with increased porosity, probably due to the fact that the soil was constantly mobilized superficially during the preparation of the seedbed. An increase in apparent density values can be observed with depth, which also implies an increase in penetration resistance, increased soil compaction, and implications that may be negative for the normal development of the plant root system. The highest value is identified at 30-40 cm, which is 1.33 g/cm³. However, the results obtained do not indicate a level of bulk density that could in any way impair the formation of an optimal root system for crop plants. In the literature, it is considered that in order to promote the development of a deep and adequate root system for plants, the bulk density values should be in the range of 1.1-1.4 g/cm³. Although at greater depths we find values of 1.32 and 1.34 g/cm³, we can conclude that these will not affect plants in the normal course of the ontogenetic cycle (Reynolds *et al*, 2002).

CONCLUSIONS

For sowing at a depth of 0-10 cm, conservative systems generally showed higher values than the conventional system. However, the CT and MT systems showed fairly similar values. The NT values were never at a level that could cause problems for the plants. At a depth of 10-20 cm, the trend in the 0-10 cm layer continued, with NT values being the highest, except that in the third year, the differences between the systems were the smallest. For a depth of 20-30 cm, based on the average values obtained, the MT system showed even lower values than CT. There is a noticeable trend towards balancing the differences between the systems, which are very close. The density in MT seems to be the one with the highest degree of stability. For the last depth interval analyzed, 30-40 cm, the variations associated with each cultivation technology are even smaller, but nevertheless, the CT system always has the lowest values.

At harvest, at a depth of 0-10 cm, we find an increase in the values of this indicator in all the systems analyzed, with NT having the highest result. At a depth of 10-20 cm, we find greater compaction in the NT system, which may also be associated with the transition period of the soil to this type of conservative system. The depth of 20-30 cm does not deviate from previous trends, as the bulk density values increase in all systems, especially in NT. For the 30-40 cm interval, we can distinguish the lowest variation of this indicator, although there is an increase here as well, and the system that most clearly shows this variation is NT.

The NT system tends to generate a higher level of bulk density as a result of soil compaction caused by the lack of pedosphere mobilization. However, the fact that the values never exceeded or reached 1.4 g/cm³, so as to impair the development of the root system, shows that NT cannot be associated with a limiting soil tillage system from the perspective of this indicator. The MT system, with intermediate values, leads to a similar conclusion. In the case of the CT system, although it presented the lowest values and considering that conservative systems do not raise the bulk density results to very high levels, we can say that it does not present any advantage in terms of soil compaction, thus calling for a transition to conservative agriculture.

REFERENCES

Busari M.A., Kukal S.S., Kaur A., Bhatt R. şi Dulazi A.A., 2015 - Conservation Tillage Impacts on Soil, Crop and the Environment; Jurnal International Soil and Water Conservation Research, v 3, p. 119-129.

Ashapure A., Jung J., Yeon J., Chang A., Maeda M., Maeda A., Landivar J., 2019 - A novel framework to detect conventional tillage and no-tillage cropping system effect on cotton growth and development using multi-temporal UAS data; Jurnal ISPRS Journal of Photogrammetry and Remote Sensing; v. 152, p. 49-64; https://doi.org/10.1016/j.isprsjprs.2019.04.003

Mihu G.-D.; Țopa, D.; Calistru, A.E.; Jităreanu, G., 2022. The influence of tillage systems on soil compaction in the corn crop. *Journal of Applied Life Sciences and Environment*, 55 (4), 391-405. https://doi.org/10.46909/alse-554072

Jităreanu G., Țopa D., Ailincăi C., Calistru A.E. și colab., 2020 - Tratat de agrotehnică, Editura "Ion Ionescu de la Brad" Iași, ISBN: 978-973-147-353-6

Giller K.E., Andersson A.J., Corbeels M., Kirkegaard J., Mortensen D., Erenstein O., Vanlauwe B., 2015 - Beyon conservation agriculture; Jurnal Frontiers in Plant Science, v.6; https://doi.org/10.3389/fpls.2015.00870

Cakpo, S.S.; Aostăcioaei, T.G.; Mihu, G.-D.; Molocea, C.-C.; Ghelbere, C.; Ursu, A.; Țopa, D.C., 2025. Long-Term Effect of Tillage Practices on Soil Physical Properties and Winter Wheat Yield in North-East Romania. Agriculture, 15, 989. https://doi.org/10.3390/agriculture15090989

Villamil B.M., Little J., Nafziger D.E., 2015 - Corn residue, tillage, nitrogen rate effects on soil properties; Jurnal Soil and Tillage Research, v. 151, p 61-66; https://doi.org/10.1016/j.still.2015.03.005

Calistru, A.E.; Filipov, F.; Cara, I.G.; Cioboată, M.; Țopa, D.; Jităreanu, G., 2024. Tillage and Straw Management Practices Influence Soil Nutrient Distribution: A Case Study from North-Eastern Romania. Land, 13, 625. https://doi.org/10.3390/land13050625

Zhao X., Liu S., Pu C., Zhang X.Q., Xue J.F., Ren Y.X., Zhao X.L., Chen F., Lal R., Zhang L.G., 2017 - Crop yields under no-till farming in China: A meta-analysis; Jurnal European Journal of Agronomy; v.84, p 67-75; https://doi.org/10.1016/j.eja.2016.11.009

Mihu G.-D.; Țopa, D.; Calistru, A.E.; Jităreanu, G., 2022. The influence of tillage systems on soil compaction in the corn crop. Journal of Applied Life Sciences and Environment, 55 (4), 391-405. https://doi.org/10.46909/alse-554072

Blanco C. H., Stone L.R., Scheleged A.J., Lyon D.J., Vigil M.F., Stahlman P.W. și Mikha M., 2009 - No-till induced increase in organic carbon reduces near surface maximum bulk density pf soils; Jurnal Soil Sciences Society of America Journal, p. 1871-1879.; DOI:10.2136/sssaj2008.0353

Mihu, G.-D.; Aostăcioaei, T.G.; Ghelbere, C.; Calistru, A.-E.; Țopa, D.C.; Jităreanu, G., 2025. Exploring Soil Hy-dro-Physical Improvements Under No-Tillage: A Sustainable Approach for Soil Health. Agriculture, 15, 981. https://doi.org/10.3390/agriculture15090981

Schmidt E.S., Villamil M. B. și Amiotti N.M., 2018 - Soil quality under conservation practices on farm operations of the southern semiarid pampas region of Argentina; Jurnal Soil Tillage Research, p. 85-94; https://doi.org/10.31545/intagr/195906

Țopa, D.-C.; Căpșună, S.; Calistru, A.-E.; Ailincăi, C., 2025. Sustainable Practices for Enhancing Soil Health and Crop Quality in Modern Agriculture: A Review. Agriculture, 15, 998. https://doi.org/10.3390/agriculture15090998

Blanco C.H. și Ruis S.J., 2018 - No-tillage and soil physical environment; Jurnal Geoderma, p. 164-200; DOI:10.1016/j.geoderma.2018.03.011

Li Y., Cui S., Chang S. X., Zhang Q. P., Jagadamma S. și Cai Y., 2019 - Residue retention promotes soil carbon accumulation in minimum tillage systems- implications for conservation tillage; Jurnal Science of the total Environment. DOI: 10.1016/j.scitotenv.2020.140147

Li Y., Chang S.X., Tian L.H. și Zhang Q.P., 2018 - Conservation agriculture practices increase soil microbial biomass carbon and nitrogen in agricultural soils- a global meta-analysis; Jurnal Soil Biology & Biochemistry, p. 50-58; DOI:10.1016/j.soilbio.2018.02.024

Titianu L., 2010 - Studiu economic privind perfecționarea structurală a producției și a sistemelor de conducere în exploarațiile agricole din câmpia Brărilei; USV "Ion Ionescu de la Brad" din Iași;

Anup K.C. și Kalu, S., 2015 - Soil Remediation and Plants in Nepal; Jurnal Soil Remediation and Plants.