Changes in soil physico-chemical properties under different land-use systems

ABSTRACT

An investigation was carried out at the Research Farm, Department of Forestry, College of Agriculture, Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur, Madhya Pradesh. The objective was to evaluate the influence of different land-use systems on the physical and chemical properties of soil during the rabi season over a span of two years (2022-23 and 2023-24). The experiment was conducted using a split-split plot design. The main plot consisted of two land-use systems: Agroforestry system (S_1) and Open system (S_2). The sub-plots were the different crop establishment methods: Broadcasting (M_1), Line sowing (M_2), and Transplanting (M_3). Within each sub-plot, four sub-sub plots were laid which represented different boron levels: Control (B_0), 1 kg B ha^{-1} as Basal (B_1), 2 kg B ha^{-1} as Basal (B_2), and ½ kg B ha^{-1} as Basal + ½ kg B ha^{-1} as foliar (B_3). The soil samples under the treatments were tested to determine the physico-chemical parameters of the soil. The results indicated that the agroforestry system had a significantly positive influence on the physical and chemical properties of the soil, in comparison to the open system. The agroforestry system demonstrated the minimal values for pH (7.07), bulk density (1.30 g cm^{-3}), and electrical conductivity (0.28 dS m^{-1}). The agroforestry system had the most elevated levels of soil organic carbon (0.72%) and water storage capacity (39.52%) as observed. The agroforestry system bore higher levels of nitrogen, phosphorus, potassium, and boron in the soil, with respective values of 290, 18.8, 191 kg ha^{-1} and 0.76 mg ha^{-1}. Therefore, this study asserts that among the different land-use systems, agroforestry is superior to the open system in terms of enhancement in soil fertility.

Keywords: Agroforestry, mustard, open system, physico-chemical properties, shisham, soil.

INTRODUCTION

The health and sustainability of agroecosystems heavily rely on the condition of the soil, making it a crucial resource (Magdoff, 2001 and Arshad & Martin, 2002). The intense agricultural practices in the tropical and sub-tropical region of the Indian sub-continent are causing a decline in soil fertility and depletion of organic matter(Scotti et al., 2015 andGomeiro, 2016). The majority of soils are insufficiently fertile to provide all the necessary nutrients for optimal growth and development (Lal, 2009). Moreover, achieving a consistent crop production and maintaining soil health over an extended period of time is challenging. Crops deplete nitrogen, phosphorous, and potassium at a higher rate than they are replenished by mineral fertilisers, resulting in nutrient mining (Jones *et al*., 2013 and Sanyal*et al*., 2014). However, this issue can be resolved by implementing agroforestry practices. Agroforestry systems are widely regarded as a comprehensive solution to the problems caused by intensive agriculture (Sarvade& Singh, 2014; Cardineal*et al*., 2021 and Pantera*et al*., 2021).

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Implementing Agroforestry Systems (AFS) is a necessary approach to diversify land use systems in order to meet the various demands of society while minimising negative impacts on the agricultural ecosystem (Udawatta*et al*., 2019 andJose 2019). Ecological interactions in Agroforestry systems offer several benefits which include improved soil fertility through nitrogen fixation (Kim &Issac, 2022), increased organic matter (Fonte *et al*., 2010), nutrient recycling (Sileshi*et al*., 2020), higher biomass production per unit area, enhanced uptake of water and nutrients (Gama-Roudrigues, 2011 and Fahad *et al*., 2022) and the provision of a protective barrier against soil erosion and wind as provided by trees (Atangan*et al*., 2014; Tomar*et al*., 2021 and Jinger*et al*., 2022). Proper selection of tree and crop species in Agroforestry systems plays a crucial role in reducing land degradation (Sharma *et al*., 2017), improving soil productivity (Fahad *et al*., 2022), ensuring land sustainability (Raj *et al*., 2019), and promoting resource use efficiency (Dhyani*et al*., 2009).

Agroforestry is regarded as a sustainable land management technique that enhances soil quality and health. Agro-forestry land use system can serve as a viable option to mitigate land degradation to some extent. Hence, this work aims to offer empirical insights into the physical and chemical features of soil under varied land use systems, specifically focussing on mustard cultivation with varying crop establishment methods and levels of boron.

MATERIAL AND METHODS

Study site

The experiment was conducted in the *Dalbergiasissoo*based agroforestry and open system at the Research Farm, Department of Forestry, College of Agriculture, Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur, Madhya Pradesh. The experimental site is situated at an altitude of 391 meters above sea level. The location of the area is at a latitude of 23^o 12' 50" north and a longitude of 79^o 57' 56" east in the Kymore Plateau and Satpura Hill agroclimatic zones of Madhya Pradesh. The climate is defined by extremely hot and dry summers, with an average highest temperature of 46°C, and extremely cold and dry winters, with an average lowest temperature of 4°C. Jabalpur receives an average annual precipitation of 1350 mm. The region is famous for its high relative humidity levels, which reach 80 to 90% during the rainy season, 60 to 75%during the summer, and 20 to 23% during the winter.

The experiment employed a split-split plot design, with land-use systems (S_1 = agroforestry and S_2 = open system) as main plot treatment, crop establishment methods namely M_1 = broadcasting (randomly scattered), M_2 = line sowing (30 x 10 cm), and M_3 = transplanting (45 x 15 cm) as sub-plot treatments. Furthermore, the four sub-sub plot treatments included different levels of boron application (B_0 = Control *i.e.*, 0 kg ha^{-1}, B_1 = 1 kg ha^{-1} as basal, B_2 = 2 kg ha^{-1} as basal, and B_3 = ½ kg ha^{-1} as basal + ½ kg ha^{-1} as foliar) in the rabi seasons of 2022–23 and 2023–24. The experiment consisted of using 24 distinct treatment combinations ($S_1M_1B_0$, $S_1M_1B_1$, $S_1M_1B_2$, $S_1M_1B_3$, $S_1M_2B_0$, $S_1M_2B_1$, $S_1M_2B_2$, $S_1M_2B_3$, $S_1M_3B_0$, $S_1M_3B_1$, $S_1M_3B_2$, $S_1M_3B_3$, $S_2M_1B_0$, $S_2M_1B_1$, $S_2M_1B_2$, $S_2M_1B_3$, $S_2M_2B_0$, $S_2M_2B_1$, $S_2M_2B_2$, $S_2M_2B_3$, $S_2M_3B_0$, $S_2M_3B_1$, $S_2M_3B_2$, $S_2M_3B_3$). The treatments were allocated randomly into three distinct replications. Mustard was grown in the plots measuring 3.6 m x15 m between the alleysof 24-year-old *Dalbergiasissoo* trees. The trees are planted with a uniform distance of 5 x 5 m. Recommended dose of fertiliser (80:40:40 N:P:K kg ha^{-1}, respectively) was supplemented to the crop.

Soil Sampling and Analysis

Prior to sowing the crop for field experiment, a comprehensive soil sample was collected to assess the initial soil condition. The purpose of obtaining a soil sample before conducting the experiment was to obtain initial data forphysico-chemical properties of soil. In order to get spatial diversity, five distinct sampling locations were chosen at random within each area and collected using an auger from the root zone at a depth of 0-15 cm.

After collection of soil samples, they were carried to the laboratory and underwent different procedures for different propeties. To achieve uniformity, the soil samples were grounded into smaller particles and any undesirable material was removed. The pH of soil was measured using a glass electrode on a digital pH meter (Piper, 1966) after allowing it to reach equilibrium for half an hour in a 1:2.5 ratio of soil to water. The soil sample's electrical conductivity was measured at 25^oC using a conductivity meter (Black, 1965) in a 1:2.5 ratio of soil to water suspension. The organic carbon content was assessed using the method developed by Walkley& Black (1934). The alkaline potassium permanganate method, as described by Subbiah&Asija (1956), was used for the determination of nitrogen available in the soil. The method used for extraction of available phosphorus was performed by following the procedure described by Olsen *et al.*, (1954). Available potassium was assessed by extracting it with 1 N ammonium acetate solution at pH 7, and the potassium concentration was measured using a flame photometer, as described by Jackson, 1973. The boron availability was estimated using the hot-water soluble method developed by Gupta (1967), which was further simplified by the utilisation of azomethine-H (John *et al.*, 1975).

Table 1: Physio-chemical properties of the soil in the experimental field

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Constituents	Initial Value (open system)	Initial Value (agroforestry system)	Methods of analysis
A. Physical compositions			
Bulk density (g cm^{-3})	1.32	1.33	Core sample (Black *et al.*,1965)
B. Chemical compositions			
Organic carbon (%)	0.68	0.55	Chromic acid rapid titration method (Walkley& Black, 1934)
Available nitrogen (kg ha^{-1})	252.20	245.88	Alkaline Permangantic Method (Subbiah&Asija, 1956)
Available phosphorus (kg ha^{-1})	12.26	11.04	Calorimeter method (Olsen *et al.*, 1954)
Available potassium (kg ha^{-1})	147.70	140.25	Flame photometer Method (Jackson, 1973)
Available boron (mg ha^{-1})	0.61	0.57	Hot-water soluble method (Gupta, 1967)
Soil pH	7.09	7.10	Glass electric pH meter (Piper, 1966)
EC (ds m^{-1})	0.29	0.30	Solu-bridge method (Black, 1965)

RESULTS AND DISCUSSION

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Effect of Land-use Systems

The influences of the land-use systems were recorded for soil physico-chemical parameters (Table 2, 3 and 4) with respect topH, EC, OC, bulk density, water holding capacity, available nitrogen, phosphorous, potassium and boron.

No significant effect on pH and electrical conductivity was observed due to the land-use system. However, agroforestry reduced the bulk density and water holding capacity compared to the open system. This might be due to increase in organic matter due to the leaf litter. Similar findings were reported by Singh *et al.*, (2018) and Mesfin&Haileselassie, (2022).

Furthermore, organic matter, available nitrogen, available phosphorous, available potassium and available boron was found to be higher under agroforestry system than the open system. This might be due to the leaf litter which fostered the availability of organic matter and nutrients which inturn increased water holding capacity under agroforestry system. These findings are in conformity with Kumar *et al.*, (2018) and Bisht*et al*., (2017).

Effect of Crop Establishment Methods

The no significant influences on soil physico-chemical parameters (Table 2, 3 and 4) *viz.*pH, EC, OC, bulk density, water holding capacity, available nitrogen, available phosphorous, available potassium and available boron were marked due to crop establishment methods. However, pH, electrical conductivity and bulk density decreased with the transplanting method. Meanwhile, organic carbon, water holding capacity and available nutrients (N, P, K and B) were recorded to be highest with transplanting.

Effect of Boron Levels

The significant influences on soil physico-chemical parameters (Table 2, 3 and 4)were marked due to boron levels were found non-significant.

Table 2: pH, Electrical Conductivity and Organic Carbon in soil as affected by crop establishment methods and boron levels under different systems

Treatments	**pH**			**Electrical Conductivity (dS m^{-1})**			**Organic Carbon (%)**		
	Y_1	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
Land-use systems									
S_1	7.08	7.07	7.07	0.28	0.29	0.28	0.70	0.73	0.72
S_2	7.10	7.11	7.10	0.29	0.30	0.29	0.57	0.59	0.58
SEm±	0.05	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.01
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	0.05	0.08	0.06
Crop Establishment Methods									
M_1	6.98	6.97	6.98	0.26	0.29	0.28	0.66	0.69	0.68
M_2	7.06	6.98	7.02	0.28	0.30	0.29	0.64	0.67	0.65
M_3	7.21	7.33	7.27	0.31	0.31	0.31	0.61	0.63	0.62
SEm±	0.07	0.36	0.21	0.02	0.01	0.01	0.02	0.02	0.02
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Boron Levels (kg ha^{-1})									
B_0	6.97	6.72	6.84	0.27	0.28	0.27	0.64	0.67	0.65
B_1	7.05	6.95	7.00	0.28	0.30	0.30	0.65	0.68	0.66
B_2	7.21	7.35	7.28	0.30	0.31	0.29	0.66	0.68	0.67
B_3	7.12	7.35	7.24	0.29	0.30	0.29	0.60	0.63	0.61
SEm±	0.07	0.25	0.15	0.02	0.01	0.01	0.02	0.02	0.02
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Y_1 – 2022-23 Y_2 – 2023-24

Table 3: Organic Carbon, Bulk density and Water holding capacity in soil as affected by crop establishment methods and boron levels under different systems

Treatments	Bulk density (g cm^{-3})			Water holding capacity (%)		
	Y_1	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
Land-use systems						
S_1	1.32	1.30	1.30	38.09	40.94	39.52
S_2	1.34	1.33	1.34	35.53	37.88	36.70
SEm±	0.03	0.01	0.02	0.07	0.01	0.03
C. D. (*P*=0.05)	0.01	0.06	0.13	0.42	0.06	0.20
Crop Establishment Methods						
M_1	1.36	1.32	1.33	36.52	39.33	37.92
M_2	1.34	1.33	1.33	36.81	39.44	38.12
M_3	1.30	1.30	1.30	37.10	39.46	38.28
SEm±	0.02	0.03	0.03	0.16	0.04	0.08
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Boron Levels (kg ha^{-1})						
B_0	1.35	1.32	1.33	36.70	39.36	38.03
B_1	1.35	1.32	1.33	36.74	39.38	38.06
B_2	1.34	1.31	1.31	36.86	39.43	38.14
B_3	1.30	1.30	1.31	36.94	39.46	38.20
SEm±	0.02	0.04	0.04	0.11	0.03	0.06
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Y_1 – 2022-23 Y_2 – 2023-24

Table 4: Available Nitrogen, Phosphorous, Potassium and Boron in soil as affected by crop establishment methods and boron levels under different systems

Treatments	Available nitrogen (kg ha^{-1})			Available phosphorous (kg ha^{-1})			Available potassium (kg ha^{-1})			Available Boron (mg ha^{-1})		
	Y_1	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**	**Y_1**	**Y_2**	**Pooled**
Land-use systems												
S_1	286	295	290	17.6	19.9	18.8	185	198	191	0.74	0.79	0.76
S_2	275	285	280	15.5	17.8	16.6	163	174	169	0.68	0.69	0.68
SEm±	3.3	3.38	3.32	0.18	0.33	0.24	1.83	2.09	1.95	0.01	0.02	0.01
C. D. (*P*=0.05)	20.1	20.6	20.2	1.07	2.03	1.47	11.1	12.7	11.9	0.05	0.09	0.06
Crop Establishment Methods												
M_1	278	288	284	16.5	18.8	17.7	173	185	179	0.62	0.67	0.64
M_2	281	290	285	16.6	18.7	17.6	175	186	180	0.74	0.75	0.74
M_3	283	292	287	16.7	18.9	17.8	176	187	181	0.76	0.79	0.78
SEm±	1.35	1.07	0.84	0.33	0.38	0.36	1.08	0.79	0.89	0.04	0.07	0.05
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Boron Levels (kg ha^{-1})												
B_0	279	289	285	16.1	18.3	17.2	174	185	179	0.66	0.69	0.68
B_1	280	289	285	16.4	18.8	17.6	174	186	180	0.68	0.71	0.69
B_2	281	290	285	17.0	19.3	18.0	175	187	181	0.93	0.73	0.73

B_3	281	291	286	16.6	19.0	18.0	175	186	180	0.76	0.82	0.79
SEm±	0.86	0.99	0.56	0.28	0.29	0.28	0.57	0.71	0.5	0.03	0.04	0.03
C. D. (*P*=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Y_1 – 2022-23 Y_2 – 2023-24

CONCLUSION

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The two-year study demonstrated that deliberately incorporating trees into agricultural land with appropriate species and effective management practices, enhances the soilphysico-chemical properties. Trees enhance water holding capacity, organic matter and nutrient availability by increasing the amount of organic matter through leaf litter, twigs and roots. Soil can be rejuvenatedby adoptingAgroforestrywhich has potential to enhance soil fertility andreduced soil deterioration. Agroforestry has the potential to rehabilitate degraded soils, boost agricultural productivity and ecologically sustainable. Nevertheless, necessary long-term, comprehensive and extended investigation for observing the alterations in the physical characteristics of soil is required.

References

Arshad, M. A., & Martin, S. (2002). Identifying critical limits for soil quality indicators in agro-ecosystems. *Agriculture, ecosystems & environment*, *88*(2), 153-160.

Atangana, A., Khasa, D., Chang, S., Degrande, A., Atangana, A., Khasa, D., ... &Degrande, A. (2014). Agroforestry for soil conservation. *Tropical agroforestry*, 203-216.

Bisht, N., Sah, V. K., Satyawali, K., & Tiwari, S. (2017). Comparison of wheat yield and soil properties under open and poplar based agroforestry system. *Journal of Applied and Natural Science*, *9*(3), 1540-1543.

Black, C. A. (1965). Methods of Soil Analysis: CA Black, Editor-in-chief. DD Evans [and Others] Associate Editors. RC Dinauer, Managing Editor. *American Society of Agronomy*.

Cardinael, R., Cadisch, G., Gosme, M., Oelbermann, M., & Van Noordwijk, M. (2021). Climate change mitigation and adaptation in agriculture: Why agroforestry should be part of the solution. *Agriculture, Ecosystems & Environment*, *319*, 107555.

Dhyani, S. K., Newaj, R., & Sharma, A. R. (2009). Agroforestry: its relation with agronomy, challenges and opportunities. *Indian Journal of Agronomy*, *54*(3), 249-266.

Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V., ... &Poczai, P. (2022). Agroforestry systems for soil health improvement and maintenance. *Sustainability*, *14*(22), 14877.

Fonte, S. J., Barrios, E., & Six, J. (2010). Earthworms, soil fertility and aggregate-associated soil organic matter dynamics in the Quesungual agroforestry system. *Geoderma*, *155*(3-4), 320-328.

Gama-Rodrigues, A. C. (2011). Soil organic matter, nutrient cycling and biological dinitrogen-fixation in agroforestry systems. *Agroforestry Systems*, *81*, 191-193.

Gomiero, T. (2016). Soil degradation, land scarcity and food security: Reviewing a complex challenge. *Sustainability*, *8*(3), 281.

Gupta U.C. (1967). A simplified method for determining hot-water soluble boron in podzol soils. Soil Sci. 103, 424-28.

Jackson, M.L. (1973).Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., NewDelhi,498.

Jinger, D., Kumar, R., Kakade, V., Dinesh, D., Singh, G., Pande, V. C., ... &Singhal, V. (2022). Agroforestry for controlling soil erosion and enhancing system productivity in ravine lands of Western India under climate change scenario. *Environmental Monitoring and Assessment*, *194*(4), 267.

John M.K., Chuah H. H. &Nduefeld J. H. (1975). Application of improved azomethine–H method for determination of boron in soils and plants. Anal. Lett. 8, 559-68.

Jones, D. L., Cross, P., Withers, P. J., DeLuca, T. H., Robinson, D. A., Quilliam, R. S., ... & Edwards□Jones, G. (2013). Nutrient stripping: the global disparity between food security and soil nutrient stocks. *Journal of Applied Ecology*, *50*(4), 851-862.

Jose, S. (2019). Environmental impacts and benefits of agroforestry. In *Oxford research encyclopedia of environmental science.*

Kim, D. G., & Isaac, M. E. (2022). Nitrogen dynamics in agroforestry systems. A review. *Agronomy for Sustainable Development*, *42*(4), 60.

Kumar, P., Mishra, A. K., Chaudhari, S. K., Basak, N., Rai, P., Singh, K., ... & Sharma, D. K. (2018). Carbon pools and nutrient dynamics under Eucalyptus-based agroforestry system in semi-arid region of north-west India. *Journal of the Indian Society of Soil Science*, *66*(2), 188-199.

Lal, R. (2009). Soils and food sufficiency: A review. *Sustainable agriculture*, 25-49.

Magdoff, F. (2001). Concept, components, and strategies of soil health in agroecosystems. *Journal of nematology*, *33*(4), 169.

Mesfin, S., &Haileselassie, H. (2022). Evaluation of soil physico-chemical properties as affected by canopies of scattered agroforestry trees on croplands. *South African Journal of Plant and Soil*, *39*(2), 153-162.

Olsen, S. R., Watanabe, F. S., Cosper, H. R., Larson, W. E. & Nelson, L. B. (1954).Residualphosphorusavailabilityinlong-timerotationson calcareoussoils. *Soil Science*, 78(2),141-152.

Pantera, A., Mosquera-Losada, M. R., Herzog, F., & Den Herder, M. (2021). Agroforestry and the environment. *Agroforestry Systems*, *95*(5), 767-774.

Piper, C. S. (1966). Soil and Plant Analysis. Hans Publishers, Bombay, India.

Raj, A., Jhariya, M. K., Yadav, D. K., Banerjee, A., &Meena, R. S. (2019). Agroforestry: a holistic approach for agricultural sustainability. *Sustainable agriculture, forest and environmental management*, 101-131.

Sanyal, S. K., Majumdar, K., & Singh, V. K. (2014). Nutrient management in Indian agriculture with special reference to nutrient mining—A relook. *Journal of the Indian Society of Soil Science*, *62*(4), 307-325.

Sarvade, S., & Singh, R. (2014). Role of agroforestry in food security. *Popular Kheti*, *2*(2), 25-29.

Scotti, R., Bonanomi, G., Scelza, R., Zoina, A., & Rao, M. A. (2015). Organic amendments as sustainable tool to recovery fertility in intensive agricultural systems. *Journal of soil science and plant nutrition*, *15*(2), 333-352.

Sharma, P., Singh, M. K., & Tiwari, P. (2017). Agroforestry: A land degradation control and mitigation approach. *Bulletin of Environment, Pharmacology and Life Sciences*, *6*(5), 312-317.

Sileshi, G. W., Mafongoya, P. L., &Nath, A. J. (2020). Agroforestry systems for improving nutrient recycling and soil fertility on degraded lands. *Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges-Vol. 1*, 225-253.

Singh, I., Rawat, P., Kumar, A., & Bhatt, P. (2018). Soil physico-bio-chemical properties under different agroforestry systems in Terai region of the GarhwalHiamalayas. *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 2813-2821.

Subbiah, B. V., &Asijah, G. L. (1956). A rapid procedure for determination of available nitrogen in soil. Current Sciences, 25, 259-260.

Tomar, J. M. S., Ahmed, A., Bhat, J. A., Kaushal, R., Shukla, G., & Kumar, R. (2021). Potential and opportunities of agroforestry practices in combating land degradation. *Agroforestry-small landholder's tool for climate change resiliency and mitigation*.

Udawatta, R. P., Rankoth, L. M., & Jose, S. (2019). Agroforestry and biodiversity. *Sustainability*, *11*(10), 2879.

Walkley and Black C. A. (1934). An examination of the different method for determining soil organic matter and a proposed modification of the chromic acid titration method, Soil Science. 37, 29-33.