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GENETIC DIVERSITY AND POPULATION STRUCTURE OF *LUPINUS ALBUS* (L.) FROM THE AMHARA REGION OF ETHIOPIA USING SEED STORAGE PROTEIN MARKERS

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Abstract: The genetic diversity in 48 lupin (*Lupinus albus* (L.) accessions collected from the Amhara region, Ethiopia, was assessed using seed storage protein markers (SDS-PAGE). A total of 30 different protein bands with sizes ranging from 11 to 100 kDa were detected. The average number of protein bands, the percentage of polymorphism, and gene diversity in the accessions were 16.96, 20.35, and 0.072, respectively. Genetic diversity estimates showed that West Gojam and Bahir Dar areas could be the most important sources for lupin genetic resources. The pair-wise comparison of genetic distances (GDs) among the accessions ranged from 0.011 to 0.378. The most distantly related accessions were accession 6, collected from the West Gojam zone, and accession 28 from the Bahir Dar area. Principal coordinate analysis (PCoA) showed the absence of a distinct group, and most of the accessions were intermixed. Population structure analysis revealed that the 48 lupin accessions could be assigned to three clusters. Similar to PCoA, no defined grouping based on geographic origin was observed. Accessions from different geographic origins being grouped together could be attributed to a common origin for the various accessions in the different zones, or it could be the result of seed-mediated gene flow among different lupin growing areas of the country.

Key words: diversity, white lupin, SDS-PAGE.

Introduction

Lupinus is a large and diverse genus of the legume family Fabaceae, containing both annual and perennial herbaceous species and some shrubby and tree types (Ainouche and Bayre, 1999). *Lupinus albus* (L.), commonly known as white lupin or lupin, is one of the cultivated plants in the genus believed to have originated in the Balkan Peninsula (Kurlovich and Kartuzova, 2002), and it has

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been cultivated in the Mediterranean region, North Africa and the Nile valley (Westphal, 1974). Lupin can grow under environmental and edaphic conditions that are not tolerated by other crops (Hill, 1977). As reviewed by Nigussie (2012), lupin is used for many purposes, which include pasture improvement, ornamentation, erosion control, soil stabilization as green manure, and pest control. It has a high protein and fiber content (Erbas et al., 2005; Tizazu and Emire, 2010). It also has positive roles in combating obesity, diabetes, and cardiovascular disease (Magni et al., 2004; Belski et al., 2010; Duranti and Morazzoni, 2011). However, the extensive use of lupin for food or feed is hindered by its alkaloid content (Yeheyis et al., 2010). In Ethiopia, it is grown mainly by subsistence farmers, and it covers 1.2% of the total pulse growing area, of which 99.2% of the produce came from the Amhara region (CSA, 2018). Compared to other legume crops grown in the country, lupin could be considered a neglected and underutilized crop.

Studying the genetic diversity of crops provides information that can be used to identify germplasms with valuable traits. Genetic diversity analysis in lupin has been carried out using agro-morphological traits (Atnaf et al., 2015), SSR markers (Atnaf et al., 2017), DArT markers (Raman et al., 2014), and ISSR markers (Oumer et al., 2015). Seed storage proteins are relatively inexpensive and informative markers and could show variation both within and between species (Shewry et al., 1995). In lupin, seed protein markers have been used to distinguish between genotypes and differentiate cultivars (Pollard et al., 1996; Vaz et al., 2004). No prior study employing seed proteins was conducted to assess the genetic diversity of Ethiopian lupin germplasm. Hence, this study was initiated to assess the utility of seed proteins for diversity assessment, assess the level of genetic variation among accessions, and assess the genetic structure of lupin collected from the Amhara region, Ethiopia.

Material and Methods

Plant materials and SDS-PAGE electrophoresis

Forty-eight lupin accessions obtained from the Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia, were used in this study (Table 1). To capture the intra-accession diversity, each accession was represented by 17 seeds. Individual seeds were ground to a fine powder with mortar and pestle. Extraction buffer (200 µl of 0.002M sodium borate) was added to 0.02 g of each sample, mixed by vortexing, and the homogenate was centrifuged at 10,000 rpm (Hermel Z233 M-2) for 5 min. The extracted crude protein was recovered as supernatant. The denaturing agent (0.02 M Tris-base (pH 8.6), 0.03 M sodium dodecyl sulphate (SDS), 8.3% glycerol, 2% β-mercaptoethanol and bromophenol blue) was added to the supernatant protein sample in a 1:1 ratio. Samples were denatured for 5 min at 90°C before electrophoresis.

Gel solution prepared from 30% acrylamide and N, N-methylbisacrylamide in a 29:1 ratio was used for electrophoresis. Proteins were separated using 5% stacking and 10% resolving gel in the Tris-glycine buffer (pH 8.3). The denatured sample (25 µl) was loaded on the gel and run at 100 volts until the tracking dye (bromophenol blue) reached the bottom of the gel following the discontinuous method of SDS-polyacrylamide gel electrophoresis (SDS-PAGE) (Laemmli, 1970). A standard protein marker (NEB P7712s) was included with each run. After electrophoresis, gels were stained overnight using a staining solution (0.25 g Coomassie blue diluted in 100 ml ethanol and 100 ml distilled water). For distaining, a mixture of ethanol and distilled water (1:1) was used.

Table 1. The list of accessions used in this study with accession code (Acc. code), accession number (Acc. no) and collection zone.

Acc. code	Acc. no.	Collection zone	Acc. code	Acc. no.	Collection zone
1	105007	East Gojam	25	239003	Agew Awi
2	105003	Bahir Dar area	26	208464	Agew Awi
3	239014	North Gondar	27	105006	West Gojam
4	239059	East Gojam	28	239020	Bahir Dar area
5	239047	West Gojam	29	239026	Agew Awi
6	259046	West Gojam	30	239057	East Gojam
7	239036	West Gojam	31	239019	West Gojam
8	239009	West Gojam	32	212754	South Gondar
9	239010	West Gojam	33	239016	West Gojam
10	238997	West Gojam	34	105001	West Gojam
11	239024	Bahir Dar area	35	105005	Agew Awi
12	239007	Agew Awi	36	238998	West Gojam
13	239018	West Gojam	37	238999	West Gojam
14	238993	Bahir Dar area	38	239000	West Gojam
15	239017	South Gondar	39	239004	Agew Awi
16	239025	Bahir Dar area	40	239001	West Gojam
17	238994	Bahir Dar area	41	239006	West Gojam
18	242265	West Gojam	42	239011	Bahir Dar area
19	216014	East Gojam	43	239060	North Gondar
20	239021	Bahir Dar area	44	239054	West Gojam
21	216016	East Gojam	45	239051	West Gojam
22	239034	West Gojam	46	239015	West Gojam
23	239005	Agew Awi	47	239012	North Gondar
24	216015	East Gojam	48	238996	Bahir Dar area

The accession number is a unique identifier number at the Ethiopian Biodiversity Institute.

Data analysis

The presence (1) or absence (0) of each band was scored using the standard protein marker as a reference. The resulting binary data matrix for the 48 accessions (816 individual seeds) was used to perform diversity analysis within and between the accessions. GenAlEx version 6.5 (Peakall and Smouse, 2012) was used to compute the percentage of polymorphic bands (PPB), gene diversity (He), the pair-wise comparison of genetic distances (GDs) among accessions and Principal coordinate analysis (PCoA). The genetic structure was analyzed using STRUCTURE 2.3.4 (Pritchard et al., 2000; Falush et al., 2003). To determine the most likely number of populations (K), a burn-in period and value of MCMC (Markov Chain Monte Carlo) were set to 100,000 replications. Assumed K values (1 to10) were checked, and to assure the consistency of the results between runs with the same K, ten replicates were run for each assumed K value. The most probable K-value was determined by following the simulation method of Evanno et al. (2005) using the web-based software STRUCTURE HARVESTER (Earl and VonHoldt, 2012).

Results and Discussion

Based on the relative mobility of seed proteins on the gel, a total of 30 protein bands with sizes ranging between 11 and 100 kDa were detected (Figure 1). The number of bands per accession ranged from 12 (accession 26) to 22 (accession 16).

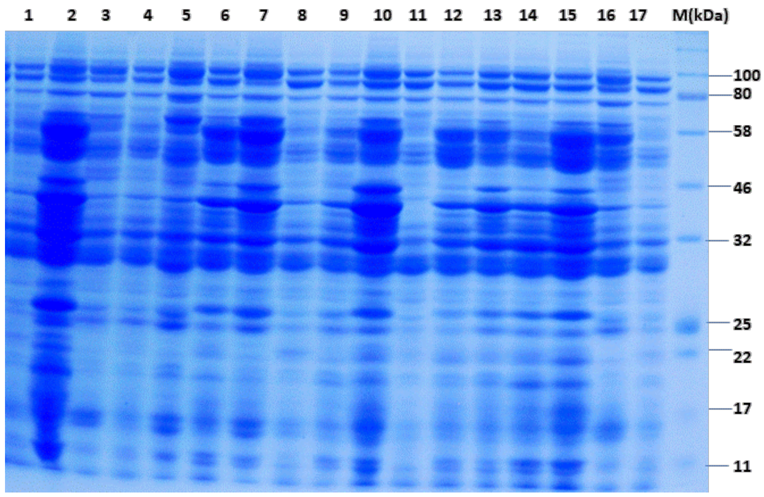

Figure 1. The representative SDS-PAGE image showing the intra-accession variability in accession 9 (acc. no 239010); numbers 1–17 indicate individual seed samples; M – Protein weight marker.

The percentage of polymorphic bands ranged from 0% to 43.33%, with an average value of 20.35%. High percentages of polymorphic loci were observed within accession 16, which was collected from the Bahir Dar area, followed by accessions 13 and 37 from the West Gojam zone (Table 2). The least band polymorphism (0.00%) was found within accessions 3, 4 and 26, which were collected from North Gondar, East Gojam, and Agew Awi zones, respectively. The highest gene diversity estimate was shown by accession 16 (He = 0.166), which was collected from the Bahir Dar area, followed by accession 13 from West Gojam (He = 0.158). Oumer et al. (2015) and Atnaf et al. (2017) reported higher values of gene diversity estimates for lupin collection from the Amhara region using ISSR and SSR markers, respectively. This showed the limited potential of seed proteins in revealing variations within accessions. Likewise, limited intra-species variations using seed proteins were also reported in legumes such as chickpea (Ghafoor et al., 2003) and groundnut (Javid et al., 2004).

Table 2. The summary of genetic diversity measures of the 48 white lupin accessions.

Accession code	N	PPB	He	Accession code	N	PPB	He
1	19	26.67	0.098	25	17	16.67	0.053
2	17	30.00	0.099	26	12	0.00	0.00
3	13	0.00	0.00	27	18	10.00	0.038
4	15	0.00	0.00	28	15	23.33	0.053
5	16	20.00	0.073	29	17	23.33	0.104
6	17	10.00	0.049	30	18	30.00	0.107
7	19	30.00	0.117	31	18	30.00	0.105
8	21	33.33	0.069	32	17	20.00	0.074
9	18	20.00	0.068	33	14	13.33	0.051
10	17	20.00	0.076	34	14	10.00	0.032
11	17	23.33	0.081	35	18	20.00	0.077
12	17	23.33	0.103	36	16	13.33	0.066
13	21	40.00	0.158	37	21	36.67	0.106
14	17	26.67	0.084	38	18	23.33	0.080
15	20	30.00	0.079	39	16	16.67	0.078
16	22	43.33	0.166	40	17	23.33	0.077
17	14	26.67	0.112	41	16	23.33	0.076
18	18	20.00	0.097	42	16	13.33	0.064
19	17	13.33	0.035	43	16	6.67	0.028
20	17	30.00	0.100	44	17	20.00	0.062
21	15	20.00	0.075	45	13	3.33	0.007
22	17	33.33	0.116	46	19	33.33	0.121
23	17	16.67	0.055	47	17	6.67	0.031
24	15	10.00	0.034	48	18	13.33	0.049
Mean					16.96	20.35	0.072

N (number of bands); PPB (percentage of polymorphic bands) and He (expected heterozygosity/gene diversity); Mean (mean values of N, PPB and He for the 48 accessions).

Based on the high number of different protein bands, the percentage of polymorphic bands and gene diversity estimates, the West Gojam and Bahir Dar areas could be the most important sources for lupin genetic resources. High gene diversity for accessions from West Gojam was also reported by earlier studies (Atnaf et al., 2015; Atnaf et al., 2017). The Bahir Dar area is another location that showed a higher level of diversity using the seed storage protein, which was not reported in the earlier studies.

The seed protein profile transformed into a binary matrix was used to calculate genetic distance. Genetic distances (GDs) between all pair-wise combinations among the 48 accessions ranged from 0.011 to 0.378 (data not shown). The most distantly related accessions were accession 6 collected from the West Gojam zone and accession 28 from the Bahir Dar area (GD = 0.378), followed by accessions 6 and 12 from West Gojam and Agew Awi (GD = 0.363) zones, respectively. The least distances were recorded between accession 47 from North Gondar and accession 27 from West Gojam (GD = 0.011) and between accession 43 from North Gondar and accession 4 from East Gojam (GD = 0.013). Close distance observed among accessions collected from different areas indicated the presence of genetic similarity among them. The principal coordinate analysis (PCoA) also revealed no distinct grouping based on geographic origin (Figure 2). The first three axes explained a cumulative variation of 44.66%. This could be due to the presence of a shared protein profile as a result of seed exchange among farmers or common origin. The existence of a dominant informal seed system might have contributed to the presence of similar genetic backgrounds for accessions collected from the different geographical areas (Forsberg et al., 2015). Similar observations were made for other legume species from Ethiopia (Shiferaw & Porceddu, 2018; Ayelign et al., 2020).

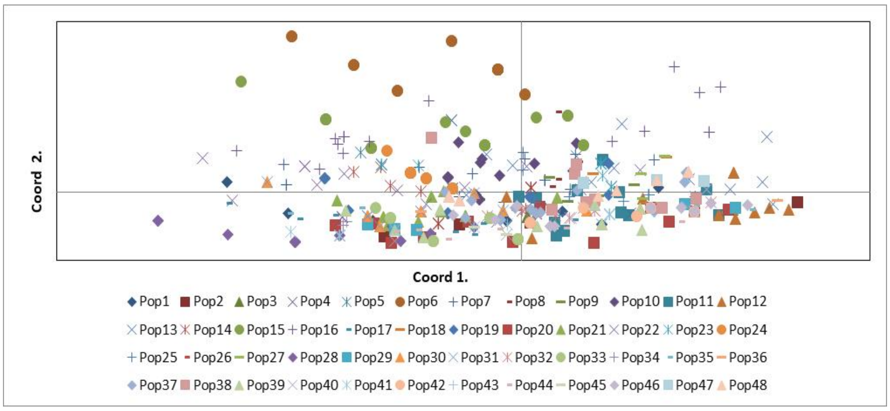

Figure 2. The principal coordinate analysis (PCoA) bi-plot showing the clustering pattern of the 816 individual samples representing the 48 lupin accessions.

The Bayesian approach-based clustering method allows to define the population structure, assign individuals to populations, and identify admixed individuals (Pritchard et al., 2000). The assignment of the 48 accessions, represented by 816 genotypes, to different populations and the determination of their population structure revealed K = 3 (three groups) to be the most likely number of clusters.

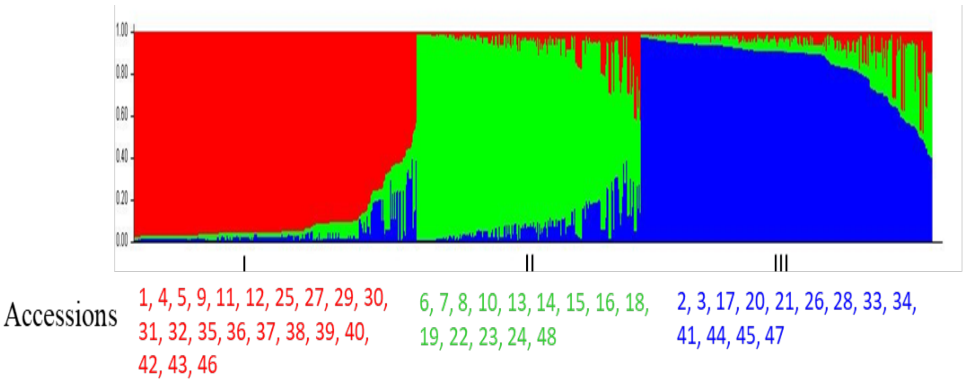

Figure 3. The model-based clustering of lupin accessions indicating the grouping of the 48 accessions into three clusters.

The first cluster (I) contained 21 accessions, while clusters II and III contained 14 and 13 accessions, respectively (Figure 3). Both PCoA and the model-based structure analysis showed substantial admixtures of lupin collections. The majority of the accessions from the Agew Awi zone were grouped in cluster I, while the rest of the accessions from different zones were grouped within the same cluster. This contrasts with the finding by Atnaf et al. (2015), where accessions from Agew Awi were distributed over different clusters. This difference could be attributed to the different types of markers used in the two studies. No defined grouping based on geographic origin was observed. The structure analysis result is largely consistent with PCoA since accessions grouped in the similar quadrat in the PCoA were also grouped in the same cluster in the structure analysis. The absence of a clear relationship between geographic origin and diversity pattern was also reported in other legume species from Ethiopia (Negisho et al., 2017; Tekalign et al., 2019). Accessions from different geographic origins being grouped together may indicate the existence of similar genetic backgrounds or a common origin for the various accessions in the different zones, or it could be the result of seed-mediated gene flow among different lupin growing areas of the country.

Conclusion

This study has analyzed the utility of seed storage proteins in detecting genetic variability in some collections of *L. albus* from the Amhara region, Ethiopia, the major growing region of the crop. Accessions from the West Gojam zone showed a higher level of diversity. The present study also indicated the Bahir Dar area as an important site for lupin diversity. The clustering of the accessions did not follow geographical origin. This could be due to the seed-mediated gene flow among different geographic zones or because of a common germplasm source. An extensive study on specific traits of germplasms from the West Gojam zone is recommended to fully realize the potential benefits of this genetic resource in breeding programs and improve the crop.

Acknowledgments

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GENETSKA RAZNOVRSNOST I STRUKTURA POPULACIJE *LUPINUS ALBUS* (L.) IZ REGIONA AMHARA U ETIOPIJI KORIŠĆENJEM PROTEINSKIH MARKERA IZ SEMENA

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R e z i m e

Genetska raznovrsnost kod 48 genotipova lupine (*Lupius albus* (L.) prikupljenih iz regiona Amhara u Etiopiji, procenjena je korišćenjem proteinskih markera skladištenih u semenu. Detektovano je ukupno 30 proteinskih traka veličina u rasponu od 11 do 100 kDa. Prosečan broj proteinskih traka, procenat polimorfizma i raznovrsnost gena u domaćim populacijama iznosio je 16, 96, 20, 35 odnosno 0,072. Procene genetičke raznovrsnosti pokazale su da oblasti Zapadnog Godžama i Bahir Dara mogu biti najvažniji izvor genetskih resursa lupine. Poređenje parova uzoraka ukazalo je da se genetska rastojanja među njima kreću od 0,011 do 0,378. Najmanje srodni bili su uzorak 6, iz oblasti Zapadni Godžam, i uzorak 28 iz oblasti Bahir Dar. Primenom analize glavnih komponenata (PCA) nisu dobijene posebne grupe, većina uzoraka je bila pomešana. Primenom populacione strukturne analize 48 uzoraka lupine podeljena su u tri klastera. Slično kao kod PCA nije primećeno-grupisanje uzoraka na osnovu geografskog porekla. Zajednička grupisanost uzoraka različitog geografskog porekla može se pripisati njihovom zajedničkom poreklu, ili bi to mogao biti rezultat protoka gena posredstvom semena između različitih oblasti uzgajanja lupine u zemlji.

Ključne reči: raznovrsnost, bela lupina, SDS-PAGE.

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EFFECTS OF ORGANIC AND MICROBIOLOGICAL FERTILIZERS ON MORPHOLOGICAL AND PRODUCTIVE CHARACTERISTICS OF TRITICALE IN THE ORGANIC FARMING SYSTEM

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Abstract: The aim of the study was to examine the impact of microbiological and organic fertilizers on morphological and productive characteristics of triticale during a three-year period (2009/10–2011/12). A two-factorial field experiment was arranged using a randomized block design with four replications. The object of the study was the triticale winter cultivar Odisej, and the following treatments were applied: a control variant without fertilization, microbiological fertilizer “Slavol” (Agrounik Serbia) 5.0 l ha^{-1}, organic fertilizer “Biohumus Royal offert” (Altamed RS) 3.0 t ha^{-1} + microbiological fertilizer “Slavol” (Agrounik Serbia) 5.0 l ha^{-1}. The results showed that the expression of the characteristics was significantly affected by the environment. The lowest values were obtained in the first year when the most unfavourable meteorological conditions were observed. The application of microbiological fertilizer had no impact on the stem length and grain weight per spike, but it significantly increased the number of fertile spikelets (3.7%), spike length (7.7%) and grain yield (18.6%). The combined application of fertilizers provided better results for all the examined characteristics, while in comparison with the control, the differences ranged from 4.3% for the number of fertile spikelets to 46.5% for grain yield. The strongest correlation was determined between the spike length and the number of fertile spikelets (r = 0.939**). The obtained results lead to the conclusion that under variable environmental

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conditions, the application of fertilizers has a significant impact on morphological and productive characteristics of triticale, and consequently on the stability of this crop production in the organic farming system.

Key words: triticale, stem height, spike length, grain weight, fertile spikelets, grain number, yield, microbiological fertilizer, organic fertilizer.

Introduction

Triticale (*x Triticosecale* Wittmack) is the first artificial type of cereals obtained by crossing wheat (*Triticum spp*.) as the mother plant and rye (*Secale cerale*) as the pollinator. Triticale possesses the genetic yield potential of wheat and the efficient use of nutritive matter of rye (Ayalew et al., 2018; Wójcik-Gront and Studnicki, 2021). It is resistant to abiotic stress (Deng et al., 2020), very modest in its soil requirements (Łysoń and Biel, 2016; Kavanagh and Hall, 2015), resistant to diseases (Góral et al., 2021), has a higher yield potential of grain (Roques et al., 2017) and forage mass (Estrada-Campuzano et al., 2012) than common wheat, especially on low-quality soils (Belović et al., 2020). Its high crop coverage enables intercepting sunlight, shading and controlling weeds (Ayalew et al., 2018), as well as protecting soil from unfavorable meteorological conditions. The strong root and the ability to efficiently absorb nitrogen enable the cultivation of triticale after the crops that leave great quantities of this macroelement in the soil, thus decreasing its leaching and running off from agricultural land (Ketterings et al., 2015).

Triticale is grown on 3,807,661 ha worldwide, with an average grain yield of 3.7 t ha^{-1}. The primary world producer is Poland (34.5% of world area) (FAO, 2019). It is mainly used as animal feed, forage crop as well as for biogas production (Randhawa et al., 2015). It is not substantially present in the human diet, although its nutritive value is significantly higher than that of common wheat (Doxastakis et al., 2002). The high presence of albumins and globulins and simultaneously a lower content of the prolamin protein (gliadin) improve the digestibility of triticale-based products (Burešová et al., 2010). Triticale has around 20% higher content of essential amino acid lysine compared to common wheat, while its aleurone layer contains a large amount of minerals and fibre (Burešová et al., 2010). Some studies have proved the presence of lunasine in the triticale grain. Lunasine is a peptide that is reported to have cancer-preventive and anti-inflammatory properties and to prevent a high level of cholesterol in the blood (Nakurte et al., 2012). In the food industry, it is very important in preparing special bread types containing different kinds of cereal grains, while it is more appropriate than common wheat in the production of cakes, muffins, tortillas and pancakes. Triticale flour obtained by complex grinding contains 14–15% of proteins (Tohver et al., 2005). However, due to the lower gluten content, triticale-based bread characteristics are estimated to be poorer than those of common wheat bread.

Triticale grain yield and quality are impacted by the genotype, agroecological conditions and growing technology, primarily the application of fertilizers. Results of previous examinations showed that the application of nitrogen (Lalević and Biberdžić, 2016), as well as the application of mineral fertilizers with the increased content of phosphorus and potassium (Lalević et al., 2019), had a positive effect on the yield and yield components of winter triticale. In addition, it was determined that the nitrogen application had a significant impact on the technological quality of this cereal grain, while the highest gluten content was recorded in the variant with the highest dose of nitrogen fertilizer (Zečević et al., 2010). From the point of view of sustainable agriculture, there are significant positive effects of organic fertilizers on morphological and productive characteristics of triticale (Roljević Nikolić et al., 2020). Parvin et al. (2020) concluded that the foliar application of 200 mg l^{-1} humic acid in the flag leaf stage led to the maximum triticale grain yield, while Kheirizadeh Arough et al. (2016) recommended the application of biofertilizers for the profitable production of triticale, particularly under water-limitation conditions. The four-year research by Sautkina and Cheverdin (2020) showed that the pre-sowing nitrogen application at a dose of 30 kg ha^{-1} could be replaced by biofertilizer application in the production technology of winter triticale.

Owing to its modest requirements regarding climatic and soil conditions and agricultural practices, triticale can be grown in marginal areas. Consequently, farmers, particularly those engaged in the organic farming system, find it increasingly popular (Feledyn-Szewczyk et al., 2020). Under low-investment conditions, triticale provides a 100% higher yield than common wheat, durum wheat and barley (Benbelkacem, 2004). Studies have shown that in the years with favorable meteorological conditions, it provides almost the identical yield in the organic and conventional field farming systems, while in the years with poorer conditions, triticale yield is slightly lower in organic farming (Kronberga, 2008). Kronberga (2008) claims that in the years with favorable meteorological conditions, the selection of the appropriate cultivar provides the possibility of obtaining a higher yield, greater protein content in the grain and higher 1,000-grain weight in organic farming than in conventional farming.

The aim of the paper is to examine the impact of microbiological and organic fertilizers on morphological and productive characteristics of triticale depending on weather conditions during three vegetation seasons in the organic farming system. Examining the relationship between morphological and productive characteristics can contribute to creating more adaptable and productive triticale cultivars in low input systems.

Material and Methods

Site description. The examination of the impact of microbiological and organic fertilizers on morphological and productive characteristics of winter triticale was conducted at “Radmilovac” (44°45′21.18″ N, 20°34′43.27″ E; 130 m a.m.s.l.) on the leached chernozem soil type of the following properties: pH (in H_2O) 8.04, N 0.13%, P_2O_5 22.18 mg, K_2O 19.10 mg, average humus content in the plow-layer 2.45%. The experiment was realized using the method of a randomized complete block design with four replications during three years (2009/10–2011/12). The elementary plot area was 6 m^2. Sowing was done manually with the sowing density of 550 germinating seeds per m^{-2}.

The weather conditions during the three-year period (Figure 1) showed certain deviations from the usual characteristics of climate in the production regions. The average annual temperatures during the examinations were significantly higher than the long-term average (10.8°C).

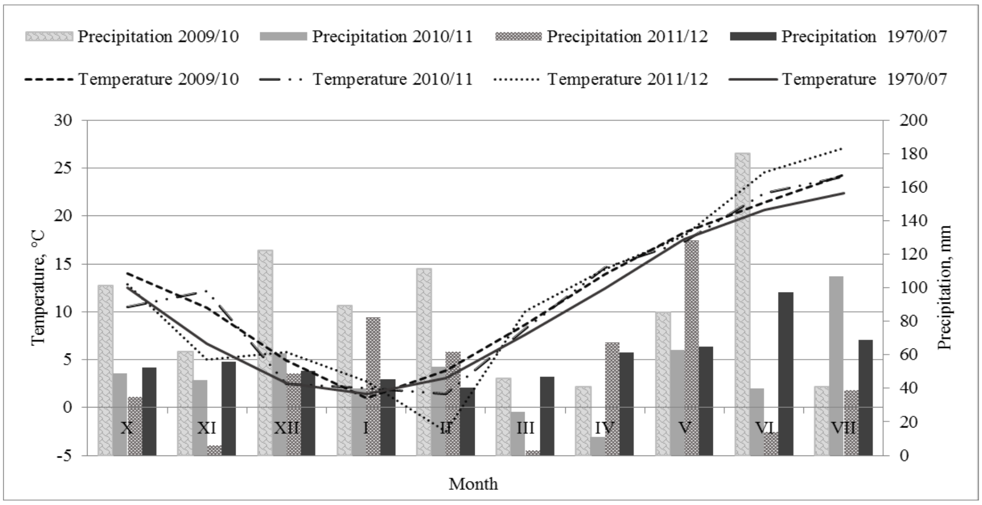

Figure 1. Average monthly air temperatures (°C) and precipitation sums (mm).
Source: Republic Hydro-meteorological Service of Serbia.

Regarding the weather conditions, the 2009/10 season was very unfavorable (12.1°C, 878 mm). The pronounced water excess in the soil during the sowing period, abundant precipitation in sensitive developmental phases (heading), as well as high temperatures in the grain ripening phases, had an unfavorable impact on the growth and development, as well on total crop productivity.

During the research year of 2010/11, the average annual temperature was higher by 0.7°C than the long-term average, with the greatest deviation in November (+5.2°C), April (+2.1°C) and June (+1.7°C), while the lower average temperatures were recorded in October (-2.0°C), February (-1.8°C) and May (-0.4°C). The precipitation sum (495 mm) was lower than the long-term average (588 mm), particularly in April (47.8 mm) and June (59.5 mm).

Although in the third year (2011/12), the precipitation sum (485 mm) was lower than the long-term average, the abundant snowfall in February and retention of snow cover slowed down the vegetation in spring. Consequently, the heading and flowering phases occurred later. In addition, higher air temperatures in June and July 2012 reduced the period of grain filling and induced accelerated maturity.

Materials. The object of the study was the triticale winter cultivar Odisej. The Odisej cultivar has an excellent resistance to cold and lodging and a very good resistance to diseases. Regarding its maturity time, it belongs to the group of very early cultivars. Its 1,000-grain weight ranges from 47 to 49 g, its hectolitre weight from 75 to 79 kg, while its protein content is at the level of 12–14%.

The experiment comprised the following treatments:

T_1 – control – without the application of microbiological and organic fertilizers;

T_2 – microbiological fertilizer (5.0 l ha^{-1});

T_3 – organic fertilizer (3.0 t ha^{-1}) + microbiological fertilizer (5.0 l ha^{-1}).

For crop nutrition in spring in the BBCH 31-33 phase, a microbiological fertilizer "Slavol" ("Agrounik" Serbia) – the liquid foliar microbiological fertilizer was used of the following content: *Bacillus megaterium* 10^{-6} cm^3, *Bacillus licheniformis* 10^{-6} cm^3, *Bacillus suptilis* 10^{-6} cm^3, *Azotobacter chroococcum* 10^{-6} cm^3, *Azotobacter vinelandii* 10^{-6} cm^3, *Derxia* sp. 10^{-6} cm^3.

To improve and maintain the soil fertility, organic fertilizer "Biohumus Royal offert" ("Altamed," Serbia) was used as the organic fertilizer, certified for use in organic farming, plowed in the autumn with the primary tillage in order to improve the content of nutritive matter, primarily phosphorus. The chemical characteristics were: pH in H_2O 8.63, N 2.2%; P_2O_5 4.8% and K_2O 2.8%.

Triticale was grown in four crop rotations: maize → winter triticale → spring barley+red clover → red clover. Tillage was done with moldboard plow in September, while the presowing preparation of soil was done with a disc harrow and a harrow in the second half of October. Crop protection was not conducted except for the mechanical weed control on the paths between the plots. The harvest was conducted by a combine harvester for experiments in the full crop maturity phase. The grain yield was measured based on the whole elementary plot, calculated at 14% moisture content and expressed in kg ha^{-1}.

Sample collection. In all three years, immediately prior to the harvest, 10 whole plants from each elementary plot were collected by random sampling.

The examined morphological characteristics were: the stem height (cm) and spike length (cm), while the following productive characteristics were determined: spike weight (g), grain weight per spike (g), number of fertile spikelets, grain number per spike and grain yield (kg ha^{-1}).

Statistical analysis. Data on the yield were analyzed using the analysis of variance (ANOVA) procedure of the Statistical Package for Social Sciences (SPSS software, 19.0). The comparisons among the different fertilization treatments were made with the least significant difference (LSD) test. The correlation analysis was performed to examine the relationship between the examined characteristics. Statistical significance was determined at the level of $p < 0.05$.

Results and Discussion

Stem height, which is a quantitative characteristic and an indirect component of grain yield, is greatly influenced not only by the genotype but by the environment as well (Đekić et al., 2019). The results of the analysis of the variance of this research showed a significant impact of the year and fertilization on the stem height (Table 1). The greatest average stem height was recorded in the third year (82.89 cm), which was significantly higher than in the first year (17%). The differences were also influenced by the fertilization treatments (Tables 2 3). The average stem height recorded in the treatment with the combined application of microbiological and organic fertilizers (80.83 cm) was significantly higher than the one in the control treatment (by 9.7%). In contrast, the independent use of microbiological fertilizer did not significantly impact the increase in the stem height (by 3.2%). The interaction of the examined factors (Y x T) did not have a significant impact on the triticale stem height, and similar results were also registered in other studies (Roljević Nikolić et al., 2020).

A spike has an important role not only as a direct holder of yield and grain, but owing to its large surface area, it also participates in photosynthesis, organic matter production and grain filling (Đekić et al., 2012). A longer spike has a greater ability to photosynthesis, which, along with mineral nutrition, directly affects the intensity of organic matter production and a larger number of fertile florets in a spikelet (Miralles and Slafer, 2007). In addition, a spike of greater length is most commonly correlated with a higher grain number per spike (Roljević Nikolić et al., 2020). Spike length was found to be significantly affected by year and fertilization (Table 1). During the three-year research, the average spike length of the cv. Odisej amounted to 10.01 cm. The greatest average spike length was recorded in the third year (11.49 cm), which was higher by 46.7% and 7.2% than in the first and the second year, respectively. There were significant differences between the fertilization treatments (Tables 2 and 3). Namely, the spike length of the cv. Odisej recorded in the treatment using the combined application of microbiological and organic fertilizers (10.60 cm) and in the treatment using only the microbiological fertilizer (10.08 cm) was higher by 13.4% and 7.7%, respectively, than in the control variant (Table 2).

Table 1. Results of the analysis of variance.

Source	Traits	Type III Sum of squares	Mean square	F	Sig.
Year	Stem height	680.217	340.109	11.138	0.001
	Spike length	67.022	33.511	70.785	0.000
	Spike weight	10.714	5.357	23.622	0.000
	Grain weight per spike	2.789	1.395	60.773	0.000
	No. of fertile spikelets	240.090	120.045	153.758	0.000
	No. of grains per spike	7129.023	3564.511	74.551	0.000
	Yield	9593706.936	4796853.468	23.001	0.000
Treatment	Stem height	234.876	117.438	3.846	0.041
	Spike length	7.043	3.522	7.439	0.004
	Spike weight	1.295	0.648	2.856	0.084
	Grain weight per spike	0.376	0.188	8.191	0.003
	No. of fertile spikelets	5.587	2.794	3.578	0.049
	No. of grains per spike	207.481	103.740	2.170	0.143
	Yield	8955456.080	4477728.040	21.471	0.000
Year x Tretment	Stem height	24.984	6.246	0.205	0.933
	Spike length	0.559	0.140	0.295	0.877
	Spike weight	0.175	0.044	0.193	0.939
	Grain weight per spike	0.011	0.003	0.115	0.976
	No. of fertile spikelets	0.261	0.065	0.084	0.986
	No. of grains per spike	129.281	32.320	0.676	0.617
	Yield	1123869.358	280967.339	1.347	0.291

The impact of the years on the spike weight was primarily expressed in the differences regarding the amount and distribution of precipitation, as well as the air temperature fluctuations. Greater soil moisture in the first year favoured weed growth, which had an additional impact on the total above-ground weight of the cultivated plants (previous research by Roljević Nikolić et al., 2017; 2020). Therefore, the average spike weight in the first year (1.67 g) was significantly lower than in the second (3.14 g) and the third year (2.8 g), i.e. by 46.8% and 40.6%, respectively. Although the impact of fertilization, as well as the interaction of the examined factors, was not significant (Table 1), it can be noticed that the spike weight in the control variant was lower than in the variants where fertilizers were applied in all years. On average, this difference amounted to 9.9% in treatment T_2, and 23.4% in treatment T_3 in comparison to the control (Table 2).

On the other hand, the grain weight per spike was significantly impacted by the fertilizer application (Table 1). The recorded average value in the T_3 treatment was greater by 19.1% and 12.1% than in T_1 and T_2, representing significant differences (Tables 2 and 3). During the research, the average grain weight per spike ranged from 1.16 g in the first research year to 1.90 g in the third year, which also represents a significant difference. Although the interaction of the studied factors (Y x T) did not significantly affect this productive characteristic, the obtained results showed that the greatest differences between the control and the variants with the applied fertilizers were registered in the first research year (T_1 – 9.8% and T_2 – 22.2%). In addition, it was determined that, in the variants with the applied fertilizers, the grain weight per spike had a smaller coefficient of variation (T_2 7.6% and T_3 6.6%) in comparison to the control (T_1 8.3%), which highlights the significance of fertilizer application from the aspect of production stability as well.

One of the most important components of cereal yield is the grain number per spike. The grain number per spike results from several parameters (spike length, number of spikelets, number of florets per spikelet), which may vary significantly depending on agro-ecological conditions. The average grain number per spike recorded for the cv. Odisej amounted to 50.86, with significant differences between the years (Tables 2 and 3). The greatest average grain number per spike was recorded in the second year (70.35), which was greater by 130.2% and 36.2% than in the first and third year, respectively. The application of fertilizers did not show a significant impact on this characteristic, but the values obtained in the control were smaller by 6.0% and 12.5% on average than in the fertilization treatments T_2 and T_3, respectively (Table 2). Examining the impact of mineral fertilizers on the productive and morphological characteristics of spelt wheat, Glamočlija et al. (2012) concluded that adding mineral fertilizers had a statistically significant impact on the stem length and spike length, while no statistical significance was recorded for the number of spikelets per spike, grain number per spike and 1,000-grain weight, although the values of these characteristics were greater in the treatment including fertilizers than in the control. These findings are in accordance with our research results.

Heading and flowering phases represent a very important determinant of seasonal and regional adaptation of cereal cultivars (Trkulja et al., 2011). The adaptations are reflected in avoiding low air temperatures in flowering time (which can cause male sterility), as well as avoiding high temperatures and droughts during the grain filling phase. The significant impact of the year was determined on the number of fertile spikelets per spike (Table 1). The average number in the third year (27.14) was significantly greater in comparison to the first (20.20) and the second year (25.63) (Tables 2 and 3). The application of microbiological fertilizer had an impact on the increase in the number of fertile spikelets by 3.7%, while the application of microbiological and organic fertilizers increased the number of fertile spikelets by 4.3%. This represents a significant difference in comparison to the control. The analysis of the data presented in Table 1 indicates that the best result of the application of microbiological fertilizer was recorded in the third year (4.0%), while the best result of the combined application of microbiological and organic fertilizers was registered in the first research year (5.8%). During the research, variation in the number of fertile spikelets was the lowest in the T_3 treatment (11.7%).

Table 2. Morphological and productive traits of the cv. Odisej in the three-year period.

Year	Treatment			Average
	T_1	T_2	T_3	
Stem height (cm)				
2009/2010	66.82	71.73	74.03	70.86
2010/2011	73.58	80.32	83.29	79.06
2011/2012	80.70	82.82	85.16	82.89
Average	73.70	78.29	80.83	
Spike length (cm)				
2009/2010	6.99	7.88	8.62	7.83
2010/2011	10.00	10.90	11.26	10.72
2011/2012	11.08	11.46	11.93	11.49
Average	9.36	10.08	10.60	
Spike weight (g)				
2009/2010	15.20	16.93	18.00	16.71
2010/2011	28.00	30.97	35.27	31.41
2011/2012	25.43	27.53	31.40	28.12
Average	22.88	25.14	28.22	
Grain weight per spike (g)				
2009/2010	1.05	1.15	1.28	1.16
2010/2011	1.64	1.72	1.96	1.77
2011/2012	1.77	1.86	2.07	1.90
Average	1.49	1.58	1.77	
Number of fertile spikelets				
2009/2010	19.60	20.27	20.73	20.20
2010/2011	25.00	25.90	26.00	25.63
2011/2012	26.47	27.53	27.43	27.14
Average	23.69	24.57	24.72	
Number of grains per spike				
2009/2010	29.90	30.60	31.20	30.57
2010/2011	64.15	69.03	77.87	70.35
2011/2012	48.73	52.23	54.03	51.67
Average	47.59	50.62	54.37	
Yield (kg ha^{-1})				
2009/2010	2,429.00	2,938.17	3,393.17	2,920.11
2010/2011	2,691.50	3,667.00	4,708.70	3,689.07
2011/2012	3,909.20	4,108.33	5,127.02	4,381.52
Average	3,009.90	3,571.17	4,409.63	

In the applied organic farming technology, the three-year average yield of the Odisej cultivar amounted to 3,664 kg ha^{-1}, which is by 40–60% lower in comparison to the yields stated by Glamočlija (2004) obtained under conventional farming conditions. The impact of the year on yield was significant and the greatest grain yield was recorded in the third year (4,381.52 kg ha^{-1}), while the significantly lower was registered in the first research year (2,920.11 kg ha^{-1}) (Tables 1 and 2). In terms of weather conditions, the vegetation season of 2009/10 was very unfavorable. Greater soil moisture had a negative impact on the mineralization of the organic fertilizer and the availability of nutritive matter. In addition, abundant precipitation occurred in the periods of the sensitive development phases, which had an unfavorable effect on the productivity of the cv. Odisej in the first year. Some other studies also underlined that the moisture excess in autumn had a negative effect on the growth and development of triticale (Wójcik-Gront and Studnicki, 2021).

Table 3. The least significant difference (LSD) test.

Traits	2009/2010–2011/2012			
	a level	Y	T	Y*T
Stem height	0.05	4.74	4.74	-
	0.01	6.50	6.50	-
Spike length	0.05	0.59	0.59	-
	0.01	0.81	0.81	-
Spike weight	0.05	0.41	-	-
	0.01	0.56	-	-
Grain weight per spike	0.05	0.13	0.13	-
	0.01	0.18	0.18	-
Number of fertile spikelets	0.05	0.76	0.76	-
	0.01	1.04	1.04	-
Number of grains per spike	0.05	5.93	5.93	
	0.01	8.13	8.13	
Yield	0.05	391.51	391.51	-
	0.01	536.93	536.93	-

Y – year; T – treatment.

The analysis of variance determined a significant impact of the examined fertilization treatments on the grain yield (Tables 1 and 3). The best result was recorded in the T_3 treatment, where the grain yield was greater by 46.5% than in the control (Table 2). The effect of fertilizer application was somewhat weaker since the recorded increase in the yield amounted to 18.6%. The positive impact of the fertilizer application on the grain yield of the Odisej cultivar in conventional farming was noticed by Lalević et al. (2019). They stated that the variant with the lowest nitrogen amount had a significantly lower yield than the other fertilization variants. The results of the descriptive analysis showed that the grain yield variations in the control (21.4%) were greater than in the variants with the applied fertilizers (T_1 – 13.5% and T_2 – 16.8%), which indicates that the application of fertilizers in the organic production of triticale was significant not only from the aspect of grain yield but also from the aspect of the stability of grain yield.

The results of the correlation analysis show that there was a positive and significant correlation between the studied traits of the Odisej cultivar (Table 4). The stem height has a positive and significant correlation with all the studied characteristics: spike length (r = 0.742**) and spike weight (r = 0.609**), number of fertile spikelets (r = 0.754**), grain number per spike (r = 0.545**) and grain weight per spike (r = 0.666**), and grain yield (r = 0.800**) (Table 3). However, the strongest correlation was determined between the spike length and the number of fertile spikelets (r = 0.939**), where a 1-cm increase in the spike length increased the number of fertile spikelets by 0.3 ($y = -0.106 + 0.315x_i$). Also, the grain weight per spike had a significant correlation with the spike length (r = 0.904**).

Table 4. The coefficient of correlation between analyzed morphological and productive characteristics of the triticale cv. Odisej cultivated in the system of organic production in the three-year period.

Traits	Stem height	Spike length	Spike weight	Grain weight per spike	Number of fertile spikelets	Number of grains per spike	Yield
Stem height	1	.742**	.609**	.666**	.754**	.545**	.800**
Spike length		1	.847**	.904**	.939**	.725**	.697**
Spike weight			1	.814**	.828**	.907**	.555**
Grain weight per spike				1	.915**	.723**	.680**
Number of fertile spikelets					1	.749**	.667**
Number of grains per spike						1	.443*
Yield							1

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level.

Grain formation and yield production occur primarily at the expense of decomposition and translocation of reserve compounds from older and photosynthetically inactive plant parts, such as the stem and older leaves, into the spike. It has been estimated that reserves of carbohydrates in the stem contribute to the total wheat yield by approximately 10–12% under optimal agro-ecological conditions and by more than 40% during droughts and heat stress conditions

(Evans and Wardlaw, 2017). Therefore, the determined strong positive correlation between the stem height and grain yield (r = 0.800**) needs attention in breeding Otherwise, a drastic decrease of stem height can significantly decrease the complete biomass, and consequently the grain yield (Madić et al., 2016).

Conclusion

Organic farming of winter triticale is characterized by a great impact of weather conditions on all the studied morphological and productive characteristics. The lowest values of all characteristics were recorded in the first year, which was characterized by the greatest amount of precipitation and the highest average air temperatures. Although fertilization had a positive impact on the examined characteristics, there were no significant effects regarding the spike weight and grain number per spike. The application of biofertilizer significantly increased the number of fertile spikelets (3.7%), spike length (7.7%) and grain yield (18.6%), while the combined application of biohumus and biofertilizer significantly increased the stem length (9.7%), spike length (13.3%), grain weight per spike (19.1%), number of fertile spikelets (4.3%), as well as the grain yield (46.5%) in comparison with the control. It was determined that the characteristics such as stem length and spike length, grain weight per spike and grain weight had the greatest coefficient of variation in the control, which highlights the significance of the organic fertilizer application not only from the aspect of the grain yield but also from the aspect of yield stability. There was a positive and significant correlation between the examined characteristics, particularly between the spike length and the number of fertile spikelets. The obtained results show that, within low input systems such as organic farming, even under very changeable agro-ecological conditions during a season, the selection of well-balanced formulas of organic and microbiological fertilizers can have a positive impact on the expression of the genetic potential of the triticale.

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UTICAJ ORGANSKOG I MIKROBIOLOŠKOG ĐUBRIVA NA MORFOLOŠKE I PRODUKTIVNE OSOBINE TRITIKALEA U SISTEMU ORGANSKE PROIZVODNJE

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R e z i m e

Cilj istraživanja bio je ispitivanje uticaja biohumusa i biofertilizatora na morfološke i produktivne osobine tritikalea u trogodišnjem periodu (2009/10–2011/12). Poljski ogled je postavljen kao dvofaktorijalni, po metodi blok sistema sa slučajnim rasporedom tretmana u četiri ponavljanja. Predmet ispitivanja bila je ozima sorta tritikalea, Odisej, a ispitivan je uticaj sledećih tretmana: kontrola bez đubrenja, biofertilizator (5,0 l ha^{-1}), biohumus (3,0 t ha^{-1}) + biofertilizator (5,0 l ha^{-1}). Rezultati su pokazali da spoljašnja sredina ima značajan uticaj na ekspresiju ispitivanih osobina. Najmanje vrednosti dobijene su u prvoj godini, koja je imala i najnepovoljnije meteorološke uslove. Đubrenje je imalo statistički značajan uticaj na većinu ispitivanih osobina. Primena biofertilizatora nije uticala na dužinu stabla i masu zrna u klasu, ali je značajno povećala broj plodnih klasića (3,7%), dužinu klasa (7,7%) i prinos zrna (18,6%). Kombinovanom primenom đubriva postignuti su bolji rezultati za sve ispitivane osobine, a razlike u odnosu na kontrolu bez đubrenja kretale su se u nivou od 4,3% za broj plodnih klasića do 46,5% kod prinosa zrna. Najjača korelaciona povezanost ustanovljena je između dužine klasa i broja plodnih klasića (r = 0,939**). Dobijeni rezultati upućuju na zaključak da, u promenljivim uslovima spoljašnje sredine, primena dobro izbalansiranih formula organskih i mikrobioloških đubriva ima značajan uticaj na morfološke i produktivne osobine tritikalea, a samim tim na stabilnost proizvodnje ovog useva u sistemu organskog gajenja.

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Ključne reči: tritikale, visina stabla, dužina klasa, masa zrna, plodni klasići, broj zrna, prinos, mikrobiološko đubrivo, organsko đubrivo.

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STAJNJAK U SRBIJI – KOLIČINE I EMISIJE GASOVA S EFEKTOM STAKLENE BAŠTE

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Sažetak: Stajnjak je otpadni tok iz stočarstva koji mogu da čine ekskrementi, prostirka, hrana i druge materije. Usled prisustva organske materije, stajnjak predstavlja značajnu formu đubriva koja se dodaje biljnim kulturama, ali čije neadekvatno skladištenje i korišćenje prouzrokuje negativne uticaje na životnu sredinu. Ciljevi ovog rada su da se odrede količine stajnjaka i alociraju u zavisnosti od veličine i vrste gazdinstava u Srbiji, i da se kvantifikuju emisije gasova s efektom staklene bašte u Srbiji poreklom od upravljanja stajnjakom. U Srbiji se generiše oko 8,6 miliona m^3 naturalnog tečnog stajnjaka i oko 20,4 miliona t svežeg čvrstog stajnjaka. Dominantne vrste stajnjaka su tečni svinjski stajnjak i goveđi čvrsti i tečni stajnjak. Od ukupne količine stajnjaka, 81% se nalazi na najmanjim gazdinstvima sa manje od 100 uslovnih grla dok se na velikim gazdinstvima sa preko 1.000 uslovnih grla, generiše oko 12% ukupne količine stajnjaka u Srbiji. Direktno iz stajnjaka se u 2020. godini emitovalo oko 23 Gg (Giga grama) CH_4 i 1 GgN_2O. Indirektno se iz upravljanja stajnjakom emituje oko 1,1 GgN_2O. Ukupne emisije gasova s efektom staklene bašte poreklom od stajnjaka iznosile su u 2020. godini oko 1.144 GgCO_{2ekv}. Zbog redukovanja stočnog fonda emisije su u opadanju, a u odnosu na 1990. godinu su manje za 36%.

Ključne reči: stajnjak, emisije, gasovi staklene bašte, stočarstvo.

Uvod

Stajnjak čine ekskrementi (feces i urin) farmski uzgajanih životinja, sa ili bez prostirke od žetvenih ostataka. Može sadržati i vodu (za čišćenje objekata), ostatke hrane, dlake odnosno perje, ali i hemijska sredstva za pranje i dezinfekciju (nepoželjno). Prema pravilniku koji definiše sporedne proizvode životinjskog

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porekla, stajnjak spada u materijal kategorije 2 prema riziku za javno zdravlje i zdravlje životinja, a njegovo upravljanje i distribucija na zemljište, omogućeno je u neprerađenom stanju jedino u slučaju da ne postoji mogućnost širenja opasnih zaraznih bolesti (Anonim, 2011).

Značaj stajnjaka kao nusprodukta stočarske proizvodnje ogleda se u tome što, uz odgovarajuću primenu, predstavlja značajan izvor hranljivih materija u biljnoj proizvodnji. Negativni aspekti generisanja i upravljanja stajnjakom su dodatni troškovi usled distribucije i uticaj na životnu sredinu (vodu, vazduh i zemljište).

Negativan uticaj na životnu sredinu stajnjaka proističe iz sadržaja organskih i neorganskih jedinjenja čijim hemijskim reakcijama dolazi do emisije određenih zagađujućih materija u vazduh, vodu i zemljište. Razgradnjom amino kiselina koje sadrže sumpor dolazi do emisija vodonik-sulfida koji je jedan od glavnih komponenti organoleptičkog zagađenja od strane stajnjaka. Anaerobnom razgradnjom organskih komponenti stajnjaka, dolazi i do emitovanja organskih volatilnih kiselina koje takođe doprinose neprijatnim mirisima, a određene vrste stajnjaka karakterišu se i visokim stepenom volatilizacije amonijaka nastalog kao posledica razgradnje uree. Neorganski azot u amonijačnoj formi (NH_3) nitrifikacijom prelazi u nitratni anjon, koji je sklon lakom prolasku i oceđivanju kroz pore zemljišta i doprinosi narušavanju kvaliteta podzemnih, ali i površinskih voda usled oceđenja. U kombinaciji sa jedinjenjima fosfora i kalijuma koja takođe mogu da se nađu u vodama usled primene stajnjaka, dovodi do zagađenja površinskih voda i eutrofikacije. Ostali negativni efekti primene stajnjaka dovode se u vezu sa povećanjem koncentracije teških metala u zemljištu i rasprostiranje semena korova. Svi nabrojani negativni efekti mogu da se svrstaju u grupu lokalno/regionalnog zagađenja i narušavanja životne i radne sredine (Burton i Turner, 2003; Zoranović et al., 2011).

Sa globalnog aspekta, stajnjak je značajan izvor gasova s efektom staklene bašte (GHG) (Chadwick et al., 2011). Stajnjak sadrži neorganski azot i mikrobiološki dostupan ugljenik i vodu, te samim tim sadrži esencijalne supstrate neophodne za proizvodnju azot-suboksida (N_2O) i metana (CH_4) (Zoranović et al., 2011). Stajnjak naročito doprinosi emisijama CH_4, s obzirom na to da stočarstvo obuhvata i uzgajanje i eksploataciju preživara (najznačajnija su goveda) čiji je feces bogat anaerobnim arhejama koje su metanogeni mikroorganizmi i upravo proizvođači CH_4. Digestivni trakt svinja i živine poseduje metanogene mikroorganizme u tragovima, ali se CH_4 svakako formira tokom skladištenja stajnjaka. Pominjani produkti nitrifikacije, nitrati, podložni su denitrifikaciji, anaerobnom mikrobiološkom procesu redukcije do elementarnog azota (N). Prilikom tog procesa denitrifikacije generiše se i N_2O. Ovako nastali N_2O naziva se direktno emitovani. Indirektno emitovani N_2O je onaj koji nastane od volatizovanog NH_3 i azotnih oksida NO_x (IPCC, 2006a, 2006b).

Globalne emisije GHG iznosile su 2010. godine približno 49 $GtCO_{2ekv}$ (ekvivalentne emisije ugljen dioksida). Prema Međuvladinom panelu o promeni klime (engl. *Intergovernmental Panel on Climate Change* – IPCC), od ukupnih emisija, ekonomski sektor kojem pripada poljoprivredna proizvodnja, tzv. AFOLU (engl. *Agriculture, Forestry and Other Land Use*) odgovoran je za približno četvrtinu svih globalnih emisija GHG. Posmatrano globalno, samo stočarstvo učestvuje sa približno jednom četvrtinom emisija u okviru AFOLU, a od toga, polovina emisija je direktna posledica postojanja i upravljanja stajnjakom (IPCC, 2014).

Prema podacima Evropske agencije za zaštitu životne sredine (engl. *European Environment Agency* – EEA), ukupne globalne emisije GHG i dalje imaju trend rasta, dok su samo određeni regioni snizili svoje emisije GHG u poređenju sa referentnom 1990. godinom. EU se naročito ističe sa smanjenjem emisija GHG od 24% do 2020. godine. U 2019. godini, u zemljama EU, uz Veliku Britaniju i Island, stajnjak je bio izvor 40.617,8 $ktCO_{2ekv}$. To predstavlja 0,9% ukupnih emisija GHG ovih zemalja. Ujedno, stajnjak doprinosi sa 8,5% u ukupnim emisijama CH_4. Od ukupnih emisija iz poljoprivrede, ova količina CO_{2ekv} predstavlja 9,5% i 18% ukupnih emisija CH_4 (EEA, 2021). Dalje tendencije u EU da se smanjuju emisije GHG, oličene u paketu propisa pod nazivom „Fit for 55”, Evropskim zelenim dogovorom i predloženim opštim ciljem da se do 2050. teritorija EU učini klimatski neutralnom teritorijom (da emisije GHG budu 0), predstavljaju osnovu za težnju ka tome da se emisije iz stajnjaka što više smanje (European Commission, 2020).

Poslednje zvanično kvantifikovane emisije GHG u Srbiji objavljene su 2017. godine od strane Ministarstva za zaštitu životne sredine (MZŽS) u Drugom izveštaju Republike Srbije prema Okvirnoj konvenciji Ujedinjenih nacija o promeni klime (MZŽS, 2017), ali postoji i Nacrt drugog dvogodišnjeg ažuriranog izveštaja Republike Srbije prema okvirnoj konvenciji UN o promeni klime iz 2020. godine (MZŽS, 2020). Što se tiče emisija GHG poreklom od stajnjaka, dokumenti sadrže određena neslaganja, na primer za 2014. godinu dokument iz 2017. godine navodi emisije za kategoriju 3.A.2 Upravljanje stajnjakom od 1.068,58 $GgCO_{2ekv}$, dok dokument iz 2020. godine navodi 455,12 $GgCO_{2ekv}$. Verovatan razlog za različite vrednosti emisija je taj što se u novijem izveštaju primenjuje napredniji Tier 2 metod obračuna emisija za stajnjak (IPCC, 2006a), u odnosu na prvi izveštaj gde se primenjuje Tier 1 metod, te samim tim drugačija vrsta podataka za proračun.

Ciljevi ovog rada su da se odrede količine svežeg stajnjaka u Srbiji i da se količine alociraju po vrstama i veličinama gazdinstava, kao i da se kvantifikuju emisije GHG poreklom od upravljanja stajnjakom.

Materijal i metode

Proračun količine stajnjaka

Određivanje količine stajnjaka podrazumeva poznavanje vrste stajnjaka na farmama, zastupljenost različitih kategorija istih vrsta životinja, vremena koje grla provode na ispaši, tehnika izđubravanja iz objekata, načina ishrane, tehnike čišćenja objekata, primene hemijskih sredstava. Na primer, goveda se u Srbiji drže na farmama gde se: koristi prostirka od žetvenih ostataka te se formirani stajnjak uklanja iz objekata na dnevnom/nedeljnom nivou; koristi se prostirka, ali se stajnjak uklanja iz objekata nakon nekoliko meseci – duboka prostirka; veće farme se karakterišu automatizovanim uklanjanjem tečnog stajnjaka iz objekta pomoću skrepera ili nekim drugim sistemima tečnog izđubravanja; kombinovani sistemi na istoj farmi za različite kategorije životinja; životinje se određeni deo vremena drže na ispaši pa praktično ni ne postoji stajnjak u smislu nusproizvoda kojim treba da se dalje upravlja; koriste se hemijska sredstva pri muži pa se deo stajnjaka iz muzilišta tretira kao otpadna voda. Zbog navedene kompleksnosti, ne postoji univerzalan način generisanja stajnjaka i jedinstvene karakteristike. Slična situacija je i kod drugih vrsta životinja. Procena količine stajnjaka koja obuhvata veći geografski region, a ne pojedinačnu farmu ili opštinu i okrug, mora da se sprovede sa visokim nivoom nesigurnosti.

Za proračun količine stajnjaka u Srbiji, usvojeno je da:

- 1 uslovno grlo (UG) goveda generiše 18 m^3 naturalnog tečnog stajnjaka (TS) (tabela 1), udela suve materije 8% (Radivojević et al., 2006). Zatim je smatrano da 92,5% te količine naturalnog stajnjaka formira sveži čvrsti stajnjak (ČS), što odgovara pretpostavci da se na farmama do 100 UG generiše samo ČS, na farmama između 100 i 1.000 UG 50% stajnjaka je u čvrstoj formi, a na farmama sa više od 1.000 UG samo 10% stajnjaka je u čvrstoj formi (tabela 2). Za formiranje čvrstog stajnjaka, smatrano je da se za prostirku koristi 5 kg slame po UG na dan (Radivojević et al., 2005).
- 1 UG svinja generiše 15 m^3 naturalnog TS (tabela 1), udela suve materije 5% (Radivojević et al., 2006). Zatim je smatrano da 37,6% te količine naturalnog stajnjaka formira sveži ČS, što odgovara pretpostavci da se na farmama do 100 UG generiše 50% ČS, na farmama između 100 i 1.000 UG 20% stajnjaka je u čvrstoj formi, a na farmama sa više od 1.000 UG se ne generiše ČS, samo tečni (tabela 2). Za formiranje čvrstog stajnjaka smatrano je da se za prostirku koristi 5 kg slame po UG na dan.
- Za proračun količine stajnjaka poreklom od živine korišćen je podatak iz tabele 1 i smatrano da je kompletan stajnjak u čvrstoj formi.
- Ogejo i Wildeus (2010) navode da koze i ovce generišu između 1,55 i 2,63 kg stajnjaka po danu. Za ovu studiju, usvojeno je da ova kategorija životinja generiše 2 kg stajnjaka po danu u formi ČS.

Slične podatke navode i Burton i Turner (2003). Princip koji navode Veljković et al. (2016) bazira se na poznavanju količina hrane i prostirke za individualne farme, te je bio neprimenjiv za procenu količina na nivou celokupne Srbije. U ovom radu korišćeni podaci o generisanju stajnjaka po UG su u skladu s informacijama dobijenim kroz personalnu komunikaciju sa vlasnicima više farmi u Srbiji.

Tabela 1. Godišnja količina stajnjaka prema vrsti životinja (Kaltschmitt et al., 2016).
Table 1. The annual amount of manure by animal species (Kaltschmitt et al., 2016).

	Goveda, m^3/UG *Cattle, m^3/LU*	Svinje, m^3/UG *Pigs, m^3/LU*	Živina, t/UG *Poultry, t/LU*
Količina stajnjaka *Manure quantity*	18,0	15,0	6,5
Udeo suve materije *Dry matter content*	11–12%	7–8%	22–23%

UG: uslovno grlo; *LU: livestock unit.*

Korišćeni su podaci Republičkog zavoda za statistiku (RZS) za 2018. godinu, sakupljeni preko ankete, koji sadrže detaljne podatke o geografskoj distribuciji, veličini poljoprivrednih gazdinstava, pravnih lica i preduzetnika (RZS, 2021). Podaci od interesa sumirani su u tabelama 2 i 3.

Tabela 2. Zastupljenost UG na gazdinstvima određene veličine u 2018. godini (RZS, 2021).
Table 2. Distribution of LU on farms of a certain size in 2018 (SORS, 2021).

Vrsta *Species*	Broj grla *Head number*	Broj UG *Number of LU*	Veličina gazdinstva, broj UG *Farm size, number of LU*			
			0–100	100–500	500–1.000	> 1.000
Goveda *Cattle*	881.152	678.487	88,4%	5,5%	1,7%	4,4%
Svinje *Pigs*	3.266.102	816.525	72,7%	5,5%	0,9%	21,0%
Brojleri *Broilers*	11.722.014	82.054	38,1%	36,8%	6,4%	18,7%
Nosilje *Laying hens*	8.996.039	125.945	60,3%	10,1%	3,9%	25,6%
Ovce *Sheep*	1.799.814	179.981	97,6%	2,3%	0,0%	0,1%
Koze *Goats*	218.397	21.840	99,3%	0,7%	0,0%	0,0%

UG: uslovno grlo; *LU: livestock unit.*

Određena gazdinstva imaju više vrsta životinja te dolazi do njihovog duplog brojanja, a to je naročito karakteristično za najmanju grupu gazdinstava koja imaju od 0 do 100 UG. Konji, magarci i druge životinje zbog malog broja grla zanemarene su u ovom radu. Za svođenje ukupnog broja grla na broj UG, grla mase 500 kg, korišćeni su koeficijenti RZS (RZS, 2021) za pojedinačne vrste životinja. S obzirom na to da se ti podaci odnose i na različite kategorije životinja u okviru iste vrste, jedinstveni koeficijent za celokupnu vrstu životinja je dobijen kombinujući podatke RZS o broju UG za 2018. godinu. Korišćeni koeficijenti za proračun UG su: goveda 0,77; svinje 0,25; brojleri 0,007; nosilje 0,014; ovce i koze 0,1.

Tabela 3. Broj poljoprivrednih gazdinstava u Srbiji u 2018. godini, u zavisnosti od broja UG (RZS, 2021).
Table 3. The number of farms in Serbia in 2018, depending on the number of LU (SORS, 2021).

Vrsta *Species*	Broj gazdinstava *Number of farms*			
	0–100 UG *0–100 LU*	100–500 UG *100–500 LU*	500–1.000 UG *500–1,000 LU*	> 1.000 UG *> 1,000 LU*
Goveda *Cattle*	129.744	287	24	18
Svinje *Pigs*	318.979	425	36	46
Brojleri i nosilje *Broilers and laying hens*	339.553	374	57	22
Ovce *Sheep*	137.607	150	8	3
Koze *Goats*	45.696	38	6	1

UG: uslovno grlo; *LU: livestock unit.*

Određivanje emisija GHG

Poslednji javno dostupni podaci RZS o stočnom fondu korišćeni su za proračun emisija GHG (RZS, 2021). U tabeli 4, dati su podaci za sve kategorije životinja koje značajnije doprinose emisijama, koji su iskorišćeni za proračun emisija definisan u uputstvima Međuvladinog panela za klimatske promene (IPCC, 2006a, 2006b). Vrednosti se ne odnose na uslovna grla. U tabelama 2 i 4, dolazi do manjih neslaganja, koja se mogu pripisati različitoj metodologiji prikupljanja podataka od strane RZS. Određene vrste životinja (konji, magarci i dr.) su zanemarene pošto, zbog malog broja grla, emisije ovih vrsta doprinose sa manje od 1% ukupnim emisijama.

Tabela 4. Stočni fond u Srbiji u hiljadama grla (RZS, 2021).
Table 4. Livestock fund in Serbia in thousands of head (SORS, 2021).

God. *Year*	Muzne krave *Dairy cows*	Goveda (ukupno) *Cattle (total)*	Svinje *Pigs*	Živina (ukupno) *Poultry (total)*	Brojleri *Broilers*	Ostala kokoš *Hens*	Ovce *Sheep*	Koze *Goats*
1990.	923	1.559	4.238	23.405	-	-	2.120	-
2010.	482	938	3.489	20.156	8.019	11.615	1.475	237
2011.	477	937	3.287	19.103	7.002	11.642	1.460	239
2012.	455	921	3.139	18.234	7.190	10.518	1.635	232
2013.	429	913	3.144	17.860	8.075	9.230	1.616	225
2014.	437	920	3.236	17.167	5.949	10.650	1.748	219
2015.	430	916	3.284	17.450	5.382	11.538	1.789	203
2016.	426	893	3.021	16.242	4.545	11.163	1.665	200
2017.	429	899	2.911	16.338	4.981	10.964	1.704	183
2018.	423	878	2.782	16.232	4.877	10.807	1.712	196
2019.	423	898	2.903	15.780	5.212	10.205	1.642	191
2020.	417	886	2.983	15.249	5.082	9.845	1.685	202

U ovom radu su određene emisije CH_4 i direktne emisije N_2O proistekle iz upravljanja stajnjakom. Takođe su određene indirektne emisije N_2O koje nastaju usled prvobitnih emisija NH_3 i NO_x, njihove redepozicije na površinu, te pratećih emisija N_2O koje nastaju usled denitrifikacije. Kompletan metod je baziran na principima vodiča definisanih od strane IPCC-a (IPCC, 2006a, 2006b). Razmotrene emisije odgovaraju IPCC potkategorijama koje nose oznaku 3.A.2 Upravljanje stajnjakom i 3.C.6 Indirektne emisije N_2O od upravljanja stajnjakom.

Za proračun emisija CH_4 i direktnih emisija N_2O korišćen je Tier 1 metod, koji zahteva najmanje podataka. Jednačine, koje su korišćene za proračun emisija, nose oznake 10.22 (za CH_4) i 10.25 (za N_2O) u IPCC vodiču (IPCC, 2006a).

Emisije CH_4 su proračunate koristeći podatke o broju životinja (tabela 4), emisione faktore CH_4 za prosečnu temperaturu od 11 °C (RHMZ, 2021), IPCC podacima o tipičnim masama i frakcijama stajnjaka kojima se upravlja u okviru sistema upravljanja stajnjakom. Razmatrane frakcije stajnjaka su ČS i TS, s tim da je kod živine razmatrano da se generiše ČS bez i sa prostirkom. Odabrani emisioni faktori i tipične mase su karakteristične za istočnu Evropu.

Emisije N_2O, direktne i indirektne, takođe su proračunate na osnovu IPCC emisionih faktora, tipičnim masama životinja, stepenom izlučivanja azota i izabranim frakcijama stajnjaka. Takođe su korišćeni podaci karakteristični za istočnu Evropu. Svi navedeni parametri za proračun sumirani su u tabeli 5.

Za indirektne emisije N_2O korišćen je Tier 1 metod iz uputstva (IPCC, 2006b), jednačine 11.9 i 11.10, čija je suština da se prvo odrede gasovite emisije kao posledica volatilizacije, odnosno ispiranja azota, a da se zatim, koristeći utvrđene emisione faktore, odredi emisija N_2O. Korišćeni parametri su sumirani u tabeli 6.

Tabela 5. Parametri za proračun emisija CH_4 i direktnih emisija N_2O (IPCC, 2006a).
Table 5. Parameters for calculation of CH_4 and direct N_2O emissions (IPCC, 2006a).

Vrsta *Species*	Emisioni faktor za upr. stajnj. CH_4, $kgCH_4$/grlu /god *Emission factor for manure man. CH_4, $kgCH_4$/head/yr*	Stepen izlučivanja azota, kgN/1000kg mase životinje/dan *Nitrogen excretion rate, kgN/1000kg animal mass/day*	Tipična masa, kg *Typical animal mass, kg*	Emisioni faktor za dir. N_2O-N emisije iz sistema upravljanja stajnjakom, kgN_2O-N/(kgN u MMS) *Emission factor for dir. N_2O-N emissions from MMS, kgN_2O-N/(kgN in MMS)*		Udeo kategorije stajnjaka kojom se upravlja na određeni način, ČS/TS *Fraction of livestock category's manure handled using MMS, SM/LM*
				ČS *SM*	TS *LM*	
Muzne krave *Dairy cows*	12,00	0,35	550,0	0,005	0,005	0,925/0,075
Ostala goveda *Other cattle*	6,00	0,35	500,0	0,005	0,005	0,925/0,075
Svinje *Pigs*	5,00	0,54	50,0	0,005	0,005	0,376/0,624
Nosilje *Laying hens*	0,03	0,82	1,8	0,005	0,001	0,5/0,5 (ČS/ČS)
Brojleri *Broilers*	0,02	0,82	0,9	0,005	0,001	0,5/0,5 (ČS/ČS)
Ovce *Sheep*	0,19	0,90	48,5	0,005	0,005	1/0
Koze *Goats*	0,13	1,28	38,5	0,005	0,005	1/0

ČS: čvrsti stajnjak; TS: tečni stajnjak; *SM: solid manure; LM: liquid manure; MMS: manure management system.*

Proračun emisija sproveden je uz pomoć *IPCC Inventory Software*, korišćenjem integrisanih faktora za korišćene metode, a nesigurnost dobijenih vrednosti treba uzimati u opsegu od 20% (IPCC, 2006a, 2006b). Faktori konverzije CH_4 i N_2O u ekvivalentne emisije CO_2 iznosili su 25 odnosno 298.

Tabela 6. Parametri za proračun indirektnih emisija N_2O (IPCC, 2006b).
Table 6. Parameters for calculation of indirect N_2O emissions (IPCC, 2006b).

Vrsta *Species*	Udeo N koji volatilizuje, % *Fraction of managed livestock manure N that volatilises, %*		Emisioni faktor za N_2O usled atmosferske depozicije N na zemljište i vodu, kgN_2O-N/($kgNH_3$-N+$kgNO_x$-N) *Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces kgN_2O-N/($kgNH_3$-N+$kgNO_x$-N)*	Udeo N koji se ispira iz stajnjaka kojim se upravlja, % *Fraction of managed livestock manure N that leaches, %*		Emisioni faktor za N_2O od ispranog N, kgN_2O-N/kgN ispranog *Emission factor for N_2O emissions from N leaching and runoff, kgN_2O-N/kgN leached and runoff*
	ČS *SM*	TS *LM*		ČS *SM*	TS *LM*	
Muzne krave *Dairy cows*	30	40	0,01	30	30	0,0075
Ostala goveda *Other cattle*	45	45	0,01	30	30	0,0075
Svinje *Pigs*	45	48	0,01	30	30	0,0075
Nosilje *Laying hens*	40	-	0,01	30	30	0,0075
Brojleri *Broilers*	40	-	0,01	30	30	0,0075
Ovce *Sheep*	12	-	0,01	30	30	0,0075
Koze *Goats*	12	-	0,01	30	30	0,0075

ČS: čvrsti stajnjak; TS: tečni stajnjak; N: azot; *SM: solid manure; LM: liquid manure; N: nitrogen.*

Rezultati i diskusija

Količine stajnjaka

U pogledu količina, najviše stajnjaka u Srbiji poreklom je od goveda, zatim svinja, peradi, ovaca i na kraju koza. U tabeli 7 prikazani su podaci o količinama generisanog svežeg ČS i naturalnog TS.

Ukupna količina ČS je približno 20,4 miliona tona. Približno 60% ČS je poreklom od goveda, dok svinje doprinose sa 25%, živina 7%, ovce 6%, a koze 1%. Ukupna količina TS je procenjena na približno 8,6 miliona m^3. Dominantno, oko 89% je poreklom od svinja, dok je ostatak poreklom od goveda. Navedene količine su za stajnjak u svežem stanju. Pri skladištenju dolazi do formiranja zgorelog ČS i negovanog odležalog TS, čije su količine manje u poređenju sa svežim stajnjakom usled gubitka vode i razgradnje suve materije. Stepen smanjenja mase (i zapremine) zavisi od načina skladištenja (Radivojević et al., 2005).

U pogledu zastupljenosti stajnjaka na gazdinstvima različitih veličina, najviše stajnjaka se nalazi na gazdinstvima koja imaju do 100 UG. To je u direktnoj relaciji sa činjenicom da je većina stočnog fonda u Srbiji locirana na porodičnim mikro gazdinstvima. Približno 90% ukupnog ČS se nalazi na ovakvim gazdinstvima i nešto malo više od polovine tečnog stajnjaka. Na velikim gazdinstvima, farmama sa više od 1.000 UG, nalazi se nešto malo manje od petine ukupnog stajnjaka u Srbiji. Pored najmanjih gazdinstava koja imaju goveda i svinje, među gazdinstvima na kojima se nalaze veće količine stajnjaka, ističu se mala gazdinstva koja uzgajaju perad i koja imaju skoro polovinu od ukupno generisanog ČS peradi. Na ovoj veličini gazdinstava nalazi se i skoro 40% tečnog goveđeg stajnjaka. Od ukupne količine tečnog goveđeg stajnjaka, 52% se nalazi na velikim gazdinstvima, a približno jedna trećina celokupnog svinjskog TS se isto nalazi na gazdinstvima ove veličine. Na velikim gazdinstvima nalazi se i oko 44% čvrstog stajnjaka peradi. Podaci o količinama stajnjaka prema poreklu, formi i zastupljenosti na gazdinstvima različitih veličina, prikazani su u tabeli 8.

Tabela 7. Količine generisanog stajnjaka u Srbiji.
Table 7. Quantities of generated manure in Serbia.

Vrsta *Species*	Tečni stajnjak, m^3 *Liquid manure, m^3*	Čvrsti stajnjak, t *Solid manure, t*
Goveda/*Cattle*	920.753	12.436.893
Svinje/*Pigs*	7.640.217	5.168.264
Brojleri/*Broilers*	-	533.352
Nosilje/*Laying hens*	-	818.640
Ovce/*Sheep*	-	1.313.865
Koze/*Goats*	-	159.430
Ukupno/*Total*	8.560.970	20.430.442

Na farmama sa preko 100 UG, koje imaju oko 78 hiljada UG goveda i 223 hiljade UG svinja generiše se 1,4 odnosno 3,3 miliona m^3 naturalnog TS goveda i svinja. Radivojević et al. (2005) navode količine od 1,9 odnosno 1,7 miliona m^3 za broj mesta na farmama za goveda (174,6 hiljada) i svinje (550 hiljada) u Srbiji 2000. godine. Razlike u rezultatima su posledica različitih pristupa određivanja količina stajnjaka i promeni kapaciteta farmi.

Tabela 8. Količine svežeg stajnjaka po veličinama gazdinstava.
Table 8. Quantities of fresh manure for different farm sizes.

Vrsta *Species*	0<UG<100 *0<LU<100*		100<UG<500 *100<LU<500*		500<UG<1.000 *500<LU<1.000*		>1.000 UG *>1.000 LU*	
	ČS, t *SM, t*	TS, m^3 *LM, m^3*	ČS, t *SM, t*	TS, m^3 *LM, m^3*	ČS, t *SM, t*	TS, m^3 *LM, m^3*	ČS, t *SM, t*	TS, m^3 *LM, m^3*
Goveda *Cattle*	11.892.013	0	371.840	337.610	114.386	103.856	58.653	479.286
Svinje *Pigs*	4.994.089	4.452.383	149.954	534.753	24.221	86.374	0	2.566.708
Brojleri *Broilers*	203.078	0	196.334	0	34.267	0	99.674	0
Nosilje *Laying hens*	493.890	0	82.744	0	32.303	0	209.702	0
Ovce *Sheep*	1.281.856	0	29.907	0	405	0	1.696	0
Koze *Goats*	158.360	0	1.064	0	0	0	5	0
Ukupno *Total*	19.023.287	4.452.383	831.843	872.363	205.581	190.230	369.731	3.045.994
Udeo u kategoriji, % *Share in category, %*	93,1	52,0	4,1	10,2	1,0	2,2	1,8	35,6
Udeo – ukupno, % *Share – total, %*	81,0		5,9		1,3		11,8	

UG: uslovno grlo; ČS: čvrsti stajnjak; TS: tečni stajnjak; *LU: livestock unit; SM: solid manure; LM: liquid manure.*

Emisije gasova s efektom staklene bašte

U tabeli 9 prikazani su podaci o emisijama CH_4 i N_2O izraženi u Gg za četiri izdvojene godine. Od 2010. do 2020. godine, ukupne emisije CH_4 poreklom od upravljanja stajnjakom su opale od 26,8 Gg do 23,5 Gg, što je pad od približno 13%. U poređenju sa referentnom 1990. godinom kada su emisije iznosile skoro 37 Gg, smanjenje u 2020. godini je iznosilo oko 36%. Emisije N_2O poreklom od upravljanja stajnjakom u 2020. godini iznosile su približno 1 Gg. Indirektne emisije N_2O usled upravljanja stajnjakom su oko 15% veće i iznosile su približno 1,1 Gg. Kod ovog gasa je takođe evidentan pad emisija u odnosu na 2010. godinu, ukupno za obe kategorije on iznosi 6,3%, tj. za 1990. godinu taj pad iznosi 27,7%.

Ukupne emisije GHG iskazane kroz CO_{2ekv} navedene su u tabeli 10. U 2020. godini emisije proistekle od upravljanja stajnjakom iznosile su oko 812 $GgCO_{2ekv}$, a indirektne emisije oko 332 $GgCO_{2ekv}$. Ukupne emisije usled postojanja stajnjaka iznosile su oko 1.144 $GgCO_{2ekv}$ u 2020. godini. U odnosu na 2010. godinu to je pad od 25%, a u poređenju sa referentnom 1990. godinom, pad je 36%. Ako se posmatraju samo emisije u kategoriji 3.A.2 Upravljanje stajnjakom, pad emisija u odnosu na 1990. godinu iznosi 40%.

Imajući u vidu vrednosti i trendove emisija GHG u Srbiji navedenih u MZŽS (2017), može da se smatra da u okviru AFOLU, upravljanje stajnjakom doprinosi sa oko 38% emisija, a u okviru ukupnih emisija GHG sa približno 2%.

Stajnjaci poreklom od životinja koji najviše doprinose emisijama GHG su svinjski i goveđi. To je logična posledica činjenice da su ove dve kategorije životinja najbrojnije i da generišu najviše stajnjaka. Preko 95% svih emisija GHG proizilazi iz stajnjaka svinja i goveda.

Tabela 9. Emisije CH_4 i N_2O u Gg za IPCC kategorije za upravljanje stajnjakom.
Table 9. Emissions of CH_4 and N_2O in Gg for IPCC categories related to manure.

Godina/*Year*	1990.		2010.		2015.		2020.	
GHG	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
3.A.2 – Upravljanje st. *Manure management*	36,888	1,439	26,785	1,023	25,316	1,024	23,476	0,968
3.A.2.a – Goveda *Cattle*	14,892	0,829	8,520	0,495	8,076	0,481	7,818	0,466
3.A.2.a.i – Muzne kr. *Dairy cows*	11,076	0,510	5,784	0,266	5,160	0,237	5,004	0,230
3.A.2.a.ii – Ostala gov. *Other cattle*	3,816	0,319	2,736	0,229	2,916	0,244	2,814	0,235
3.A.2.c – Ovce *Sheep*	0,403	0,265	0,280	0,185	0,340	0,224	0,320	0,211
3.A.2.d – Koze *Goats*	0,000	0,000	0,031	0,033	0,026	0,029	0,026	0,029
3.A.2.h – Svinje *Pigs*	21,190	0,328	17,445	0,270	16,420	0,254	14,915	0,231
3.A.2.i – Živina *Poultry*	0,403	0,017	0,509	0,040	0,454	0,036	0,397	0,031
3.C.6 – Ind. emisije N_2O *Ind. N_2O emissions*	-	1,441	-	1,200	-	1,185		1,114

U poređenju sa zvaničnim podacima (tabela 11), u ovom radu su emisije relativno slične sa vrednostima navedenim u Drugom zvaničnom izveštaju (MZŽS, 2017). Prosečno su za IPCC kategoriju 3.A.2 dobijene vrednosti oko 15% manje, dok je za kategoriju 3.C.6 prosek emisija oko 6% veći. U poređenju sa Nacrtom drugog ažuriranog izveštaja (MZŽS, 2020), razlika je značajnija, pa za navedene kategorije iznosi 47,3% odnosno 55,9%. Važno je napomenuti da su vrednosti koje se navode u ažuriranom izveštaju obračunate koristeći Tier 2 IPCC metod koji se smatra pouzdanijim pošto podrazumeva detaljnije podatke o stočnom fondu i pouzdanije emisione faktore karakteristične za razmatranu zemlju.

Tabela 10. Emisije GHG u $GgCO_{2ekv}$ za IPCC kategorije za upravljanje stajnjakom.
Table 10. GHG emissions in $GgCO_{2eq}$ for IPCC categories related to manure.

Godina/*Year*	1990.	2010.	2011.	2012.	2013.	2014.
3.A.2 – Upravljanje st. *Manure management*	1.351,125	974,456	942,027	917,204	908,979	930,858
3.A.2.a – Goveda *Cattle*	619,266	360,495	359,371	350,949	344,263	347,680
3.A.2.a.i – Muzne kr. *Dairy cows*	428,747	223,896	221,573	211,354	199,277	202,993
3.A.2.a.ii – Ostala gov. *Other cattle*	190,519	136,599	137,797	139,594	144,986	144,687
3.A.2.c – Ovce *Sheep*	89,155	62,030	61,399	68,759	67,960	73,511
3.A.2.d – Koze *Goats*	0,000	10,752	10,842	10,525	10,207	9,223
3.A.2.h – Svinje *Pigs*	627,541	516,633	486,722	464,807	465,547	479,170
3.A.2.i – Živina *Poultry*	15,163	24,546	23,694	22,165	21,002	21,274
3.C.6 – Ind. emisije N_2O *Indirect N_2O emissions*	429,418	357,600	350,150	342,402	342,700	350,448
Godina/*Year*	2015.	2016.	2017.	2018.	2019.	2020.
3.A.2 – Upravljanje st. *Manure management*	938,162	883,323	871,974	838,011	866,315	812,369
3.A.2.a – Goveda *Cattle*	345,327	337,777	340,069	332,789	338,780	334,196
3.A.2.a.i – Muzne kr. *Dairy cows*	199,741	197,883	199,277	196,490	196,490	193,703
3.A.2.a.ii – Ostala gov. *Other cattle*	145,586	139,894	140,793	136,299	142,290	140,493
3.A.2.c – Ovce *Sheep*	75,235	70,020	71,660	71,997	69,053	70,882
3.A.2.d – Koze *Goats*	9,209	9,073	8,302	8,892	8,665	9,164
3.A.2.h – Svinje *Pigs*	486,278	447,334	431,046	411,944	429,861	441,707
3.A.2.i – Živina *Poultry*	22,114	19,119	20,897	12,389	19,956	19,299
3.C.6 – Ind. emisije N_2O *Indirect N_2O emissions*	353,130	332,270	333,760	325,714	331,078	331,972

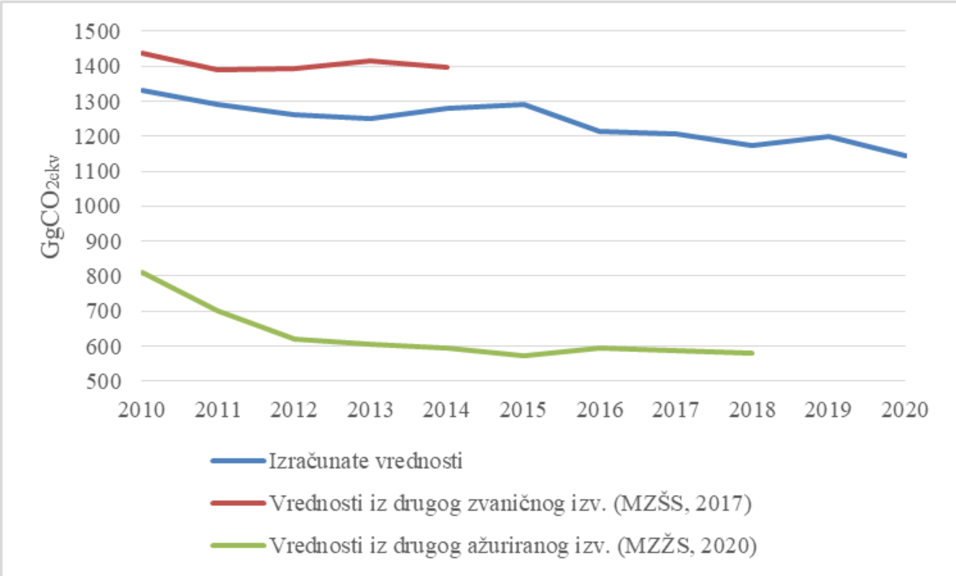
Karakteristično i za podatke izračunate u ovom radu i za dva izveštaja MZŽS je pad u emisijama GHG (slika 1). To je direktna posledica redukovanja stočnog fonda, naročito u govedarstvu. Praktično je cilj u pogledu smanjenja emisija GHG od upravljanja stajnjakom, u poređenju sa 1990. godinom, ispunjen s obzirom na to da je smanjenje emisija veće od 20%.

To ne treba da bude razlog da se problem stajnjaka tj. zagađenje životne sredine koje generiše, dalje ne razmatra. Stajnjak predstavlja supstrat za proizvodnju biogasa, a kroz proces anaerobne fermentacije kojim je podvrgnut u tom procesu, smanjuju se emisije GHG, ali i uklanja njegov potencijal ka gasovitim emisijama NH_3 i drugih gasovitih jedinjenja, stabilizuje se organska materija, a proizvod razgradnje koji se naziva ostatak fermentacije ima bolje karakteristike od samog stajnjaka u pogledu poboljšavanja karakteristika zemljišta. U Srbiji se trenutno prerađuje oko 250.000 tona stajnjaka (oko 33% je ČS) na biogas postrojenjima, mahom sa velikih gazdinstava, farmi sa preko 1.000 UG (lična komunikacija). Ova praksa bi trebalo da se proširi s obzirom na broj potencijalnih postrojenja koja treba da se izgrade u narednom periodu (MRE, 2021). Potencijalna mera za buduće veće angažovanje stajnjaka sa malih gazdinstava koja imaju od 100 do 500 UG je podsticanje malih biogas postrojenja (Đatkov et al., 2021), a gazdinstva koja imaju manje od 100 UG, rešenje za tretman stajnjaka u biogas postrojenjima je udruživanje ili prodaja stajnjaka velikim biogas postrojenjima.

Tabela 11. Podaci MZŽS o emisijama GHG za upravljanje stajnjakom.
Table 11. Data of the Ministry of Environmental Protection about GHG emissions related to manure management.

Godina/ *Year*	Drugi zvanični izveštaj (MZŽS, 2017) *The second official report (MEP, 2017)*			Drugi ažurirani izveštaj (MZŽS, 2020) *The second revised report (MEP, 2020)*		
	IPCC kategorija *IPCC category*		Ukupno *Total*	IPCC kategorija *IPCC category*		Ukupno *Total*
	3.A.2	3.C.6		3.A.2	3.C.6	
1990	1.555,19	400,86	1.956,05	728,16	222	950,16
2000	1.319,03	352,29	1.671,32	621,94	190	811,94
2005	1.194,71	329,23	1.523,94	534,1	165	699,1
2010	1.104,04	331,58	1.435,62	473,47	147	620,47
2011	1.071,78	317,35	1.389,13	461,44	144	605,44
2012	1.069,96	322,88	1.392,84	454,76	140	594,76
2013	1.083,53	332,08	1.415,61	438,18	135	573,18
2014	1.068,58	329,14	1.397,72	455,12	140	595,12
2015	-	-	-	447,54	139	586,54
2016	-	-	-	441,77	137	578,77

MZŽS: Ministarstvo zaštite životne sredine; *MEP: Ministry of Environmental Protection.*



Slika 1. Desetogodišnji trend ukupnih emisija GHG proisteklih iz upravljanja stajnjakom.
Figure 1. A ten-year trend of total GHG emissions derived from manure management.

Proračun emisija GHG je bitna obaveza prema okvirnoj konvenciji UN o promeni klime. IPCC uputstva forsiraju što kvalitetnije proračune čime se formira pouzdanija slika o situaciji u pogledu emisija GHG, a samim tim i o poželjnim merama za njihovo smanjenje. U Srbiji, Drugi ažurirani izveštaj (MZŽS, 2020) ukazuje na to da se teži korišćenju Tier 2 metoda proračuna emisija, što je pozitivna stvar. Za buduća istraživanja, ukoliko se teži daljem unapređenju korišćenja Tier 1 metoda, poseban naglasak treba da se stavi na što detaljnijem sakupljanju podataka o vrstama zastupljenih svinja i goveda, njihovim masama, stepenu izlučivanja azota, udelima ČS i TS na gazdinstvima, emisionim faktorima za CH_4 i N_2O, emisionim faktorima volatilizacije i ispiranja azota. Ukoliko se teži primeni Tier 2 metoda, svim navedenim podacima treba da se dodaju i detaljni podaci o ishrani životinja i podacima o praksi držanja životinja u objektima i fizičko-hemijskim karakteristikama stajnjaka.

Zaključak

Dominantne forme stajnjaka u Srbiji su tečni svinjski i čvrsti i tečni goveđi. Oko 81% stajnjaka se nalazi na farmama sa manje od 100 UG, oko 12% na velikim farmama sa preko 1.000 UG, a ostatak na malim farmama koje imaju između 100 i 1.000 UG.

Emisije GHG u 2020. godini iznosile su oko 1.144 $GgCO_{2ekv}$. Približno 70% su u formi CH_4, a ostatak u formi N_2O. U poređenju sa 1990. godinom, emisije GHG poreklom od upravljanja stajnjakom su manje za 36%, što je direktna posledica smanjenja stočnog fonda.

Rezultati mogu da posluže za definisanje mera za monitoring i smanjenje emisije GHG iz sektora upravljanja stanjakom.

Dalja istraživanja u ovoj oblasti treba da se usmere na unapređenje procene količina stajnjaka i emisija GHG, što bi podrazumevalo sakupljanje detaljnih podataka o stepenu generisanja stajnjaka za pojedinačne forme životinja i niz podataka o načinu upravljanja stajnjakom, karakteristikama ishrane životinja i emisionih faktora hemijskih jedinjenja koja se emituju iz stajnjaka i teritorijalnoj raspodeli stajnjaka po regionima u Srbiji. Za primenu Tier 2 modela za procenu emisija, važno je i prikupiti podatke o načinu i kapacitetima skladištenja, kao i praksi iznošenja stajnjaka na polja.

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MANURE IN SERBIA – QUANTITIES AND GREENHOUSE GAS EMISSIONS

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A b s t r a c t

Manure is a by-product at agricultural farms that can consist of excrement, bedding, food, and other substances. Manure is a significant form of organic fertilizer, but it negatively impacts the environment. The objectives of this study are to determine the quantities of manure and classify them depending on the size and type of farms in Serbia and to quantify greenhouse gas emissions in Serbia from manure management. About 8.6 million m^3 of fresh liquid manure and about 20.4 million tons of fresh solid manure are generated in Serbia. The dominant types of manures are liquid pig manure and cattle solid and liquid manures. Approximately 81% of the total amount of manure is located at farms with less than 100 livestock units. In Serbia, at large farms with over 1,000 livestock units, about 12% of the total amount of manure is generated. In 2020, about 23 Gg of CH_4 and 1 Gg of N_2O were emitted directly from manure. About 1,1 Gg of N_2O is emitted indirectly from manure management. Total emissions of greenhouse gases originating from manure in 2020 amounted to about 1,144 $GgCO_{2eq}$. Greenhouse gas emissions are declining due to the reduction of livestock, so in comparison to 1990, they are reduced by 36% for this sector.

Key words: manure, emissions, greenhouse gases, livestock.

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THE IMPACT OF PROFITABILITY AND PRODUCTIVITY ON THE RISK OF BANKRUPTCY FOR AGRICULTURAL AND FOOD COMPANIES IN VOJVODINA

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Abstract: The paper deals with agricultural and food companies which operated on the territory of Vojvodina in 2019. The study analyzed the risk of bankruptcy measured by the Altman's Z-score method, as well as the profitability and productivity of the observed companies. The aim of the study was to use a multiple regression model to determine the impact of profitability and productivity on the risk of bankruptcy for agricultural and food companies of different sizes (including micro, small, medium and large companies) as well as to compare the results for these two sectors. The comparison of agricultural and food sectors was made according to the size of the companies. The obtained results indicated that profitability has a statistically significant positive impact on the risk of bankruptcy for micro and large agricultural companies, while for small agricultural companies, the risk of bankruptcy is statistically significant and positively affected by productivity. The risk of bankruptcy for medium-sized agricultural companies is not affected by the examined indicators. In addition, regression analysis indicated that the risk of bankruptcy for micro and small food companies has a statistically significant positive impact on profitability. In contrast, for medium and large food companies, the risk of bankruptcy is not affected by the observed variables.

Key words: profitability, productivity, bankruptcy, agriculture, food industry, Vojvodina.

Introduction

The risk of bankruptcy is one of the major risks in the modern business environment. Bankruptcy occurs when a company is not able to meet its obligations to creditors, i.e. when the value of the debt is higher than the value of the assets. Predicting bankruptcy is an important issue for many users of financial statements, including banks, investors, rating agencies, auditors, insurance

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companies and legislators (Lifschutz and Jacobi, 2010). Most studies dealing with business management include bankruptcy studies (Georgeta and Georgia, 2012). Bankruptcy studies usually aim to determine the impact of different financial ratios on the risk of bankruptcy for companies, which also applies to the studies dealing with the risk of bankruptcy for agricultural and food companies.

A large number of bankruptcy studies dealing with agricultural and food companies have been conducted worldwide.

The bankruptcy risk assessment of companies on the Romanian stock exchange was performed by Burja and Burja (2013). Using the Altman's Z-score model, the authors assessed the risk of bankruptcy for 12 agricultural companies for the period 2007–2012. The results of the study revealed that most of the observed companies were at a certain risk of bankruptcy, i.e. they operated in the gray zone. Aleksanyan and Huiban (2016) examined the impact of productivity and lending costs on the risk of bankruptcy for food companies in France for the period 2001–2012. The results of this study showed that the productivity of the company is an important indicator of bankruptcy and that productivity begins to decline three years before the bankruptcy. In addition, it was found that lending costs have a statistically significant positive impact on the likelihood of bankruptcy for the observed companies. Boratyńska and Grzegorzewska (2018) analyzed the application of the fsQCA method for predicting bankruptcy on a sample of 14 agricultural companies from Poland. In addition, the authors evaluated the application of 35 already known bankruptcy prediction models and compared these methods with the fsQCA method. Apan et al. (2018) investigated the risk of bankruptcy for 18 Turkish food companies by applying two models: The Altman's Z-score model and the VIKOR model. For the period 2008–2014, the findings of this study showed that the VIKOR model is more suitable for assessing the risk of bankruptcy for the observed companies. The risk of bankruptcy for milk processing companies in Belarus was investigated by Kontsevaya et al. (2019). The authors used financial ratios of 11 models to predict the bankruptcy of 6 large processing companies, revealing that the risk of bankruptcy in each year was unstable and that such condition was caused by a number of internal and external factors. Vavrek et al. (2021) analyzed the risk of bankruptcy on a sample of 469 Slovakian agricultural companies in 2016 by applying the Altman's Z-score model, Taffler's model and Bonity Index. It was found that the Altman's Z-score model and Bonity Index accurately predict the risk of bankruptcy for the observed sample of agricultural companies, while the Taffler's model shows certain contradictions.

Studies dealing with the risk of bankruptcy for agricultural and food companies have also been conducted in our country. Rajin et al. (2016) assessed the risk of bankruptcy for five agricultural companies from the Republic of Serbia for the period 2010–2013, by applying three models for predicting the risk of bankruptcy: The Altman's Z-score model, the Kralicek's DF model and the

Kralicek's Quick test. By comparing the obtained results, the authors found that the Kralicek's Quick test is the most suitable model for assessing the risk of bankruptcy for the observed companies. Vukadinović et al. (2018) applied three models for assessing the risk of bankruptcy (Altman's Z-score model, Kralicek's Quick test and balanced growth model) for three agricultural companies for the period 2014–2016. The analysis determined that all three companies were stable and that they were not at risk of bankruptcy. Tekić et al. (2020) carried out an assessment of the bankruptcy risk for milling companies from Vojvodina, for the period 2015–2019. By applying the Altman's Z-score model and the Kralicek's Quick test on a sample of five medium-sized companies, it was determined that both models are adequate for assessing the risk of bankruptcy of the observed companies.

This study deals with agricultural and food companies which operated in Vojvodina in 2019. The companies were grouped according to their size, and the aim was to determine the effect of productivity and profitability on the risk of bankruptcy, measured by the Altman's Z-score for different sizes of companies. The aim of this paper was also to compare the results obtained for companies from the agricultural and food sectors.

Materials and Methods

Sample and data sources

The research data were obtained from the financial statements of agricultural and food companies operating on the territory of Vojvodina, available on the website of Business Registers Agency of the Republic of Serbia. The companies were grouped by their size into micro, small, medium and large companies, according to the Law on Accounting ("Official Gazette of RS", No. 73/2019). Under the provisions of this Law, micro legal entities include legal entities that do not exceed two of the following three criteria: the average number of employees – 10, the operating income of 700,000 EUR and the average value of operating assets – 350,000 EUR. Small legal entities include the legal entities that exceed the above criteria for micro companies but do not exceed two of the following three criteria: the average number of employees – 50, the operating income of 8,800,000 EUR and the average value of operating assets – 4,400,000 EUR. Medium-sized legal entities are the legal entities that exceed two of the three criteria referring to small entities. However, they do not exceed two of the following criteria: the average number of employees – 250, operating income of 35,000,000 EUR and the average value of operating assets – 17,500,000 EUR. Large legal entities include the legal entities that exceed two of the three above criteria referring to medium-sized entities.

On the territory of Vojvodina, there were 1284 agricultural companies actively operating at the end of 2019, including 938 micro companies, 272 small companies, 66 medium-sized companies and 8 large companies (Business Registers Agency of the Republic of Serbia).

At the end of 2019, there were 700 food companies actively operating in Vojvodina, including 532 companies classified in the category of micro companies, 99 in the category of small companies, 51 in the category of medium-sized companies and 18 in the category of large companies (Business Registers Agency of the Republic of Serbia).

Baseline models

In order to determine the impact of productivity and profitability on the assessment of the bankruptcy risk for the observed companies, the research data were first processed using standard statistical tools of descriptive statistics, which was followed by the application of multiple regression.

The risk of bankruptcy

The literature on the risk of bankruptcy mainly refers to the application of different bankruptcy prediction models. The oldest and most commonly used model is the Altman's Z-score model, which was developed in 1968 based on a sample of companies from the US market (Altman, 1968). The sample consisted of 66 manufacturing companies, including 33 companies that went bankrupt and 33 companies which were active. The method of multiple discriminant analysis was used to measure the impact of 22 financial ratios on the bankruptcy of the companies, and it was determined that 5 financial ratios had a significant impact on the risk of bankruptcy for the observed companies. Each of the financial ratios was assigned appropriate weights, providing the function of the following form:

$$Z = 1.2 \cdot X_1 + 1.4 \cdot X_2 + 3.3 \cdot X_3 + 0.6 \cdot X_4 + 1.0 \cdot X_5 \qquad (1)$$

Z – the value of the discriminant function,
X_1 – the ratio of working capital to total assets,
X_2 – the ratio of retained earnings to total assets,
X_3 – the ratio of earnings before interest and tax (EBIT) to total assets,
X_4 – the ratio of the market value of equity to total liabilities and
X_5 – the ratio of sales to total assets.

Indicator X_1 shows the liquidity of the company. Indicator X_2 was obtained as the ratio of retained earnings to total assets, and it indicates cumulative profitability of the company, also providing information on the age of the company (Bryan et al., 2013). Indicator X_3 was calculated as the ratio of gross profit to total assets, showing the company's profit rate, i.e. profitability. Indicator X_4 is a leverage measure, while indicator X_5 measures the asset turnover, i.e. it shows how efficiently the company uses the assets to generate sales.

Based on the obtained Z values, the companies were classified into three groups. The companies with a Z-score value above 2.67 were considered financially stable and were classified in the safe zone. If the value of a Z-score is between 1.81 and 2.67, it is considered that the business is financially unstable, but there is a chance of recovery, so these companies were classified in the gray zone. The companies with a Z-score value below 1.81 are the companies that will go bankrupt, and they are in the distress zone (Altman, 1968).

Productivity

Labour productivity measures how efficiently the company uses labour as a vital resource of the company (Krstić and Janković-Milić, 2003). Productivity is the ratio between total output and labor input. For the purposes of analyzing productivity, the following expression was used in this paper:

$$Productivity = \frac{Net\ business\ output}{No.of\ employees} \quad (2)$$

Higher productivity means that companies increase production using less input, which results in costs reduction (Bryan et al., 2013). Productivity is increased by intensifying production, i.e. by applying the most efficient available production technology.

Profitability

Profitability, as an indicator of economic success, reflects the primary function of the business determined as the ratio between profit, as the final business output, and the operating assets. The main goal of every company is to achieve maximum profit with minimum investment. In this study, profitability was calculated using the following expression:

$$Profitability = \frac{Net\ business\ output}{Total\ operating\ assets} \times 100 \quad (3)$$

The profitability of a company is necessary for the formation of financial resources, as well as for the expanded reproduction and improvement of both organizational and technological aspects of production. Stability and increased profitability are achieved by increasing the return on fixed and current assets, their optimal structure and intensification of production.

The assessment of the company position measured by the Altman's Z-score model is a complex measurement obtained by using five indicators that should be positively affected by labor productivity and profitability, as was examined in this study.

Regression analysis

The statistical analysis of the data was performed using the method of multiple regression to determine whether there is an impact of productivity and profitability on the assessment of credit risk of the observed companies. Regression analysis is used to assess the value of a dependent variable based on one or more independent variables (Mutavdžić and Đorić-Nikolić, 2018).

The applied regression model has the following form:

$$\hat{Y} = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_p X_{pi} + \varepsilon_i \quad (4)$$

where $\hat{Y}$ is the value of a dependent variable, $X_{1i}, X_{2i}, \ldots, X_{pi}$ are the values of independent variables, while $\beta_1, \beta_2, \ldots, \beta_p$ are partial regression coefficients, which indicate the influence of individual independent variables on the dependent variable, provided that other regression parameters are held constant. Parameter α is the average initial level of the dependent variable, while ε_i is a random error of the model (Hadživuković, 1991). The statistical significance of the defined model was determined using the variance analysis for regression (Novaković, 2019).

In our models, Y is the risk of bankruptcy, measured by the Altman's Z-score, X_1 is profitability, determined as the rate of return on total operating assets (%), X_2 is productivity, determined as the net outcome per employee (RSD/employee) and ε_i is a random error.

In addition to regression analysis, the study also included correlation analysis performed by calculating multiple correlation coefficients, coefficients of multiple determination and adjusted coefficients of multiple determination. The software used for statistical data processing was the STATISTICA 14 software package.

Results and Discussion

The main indicators of descriptive statistics were calculated for the observed agricultural companies in Vojvodina (Table 1).

According to the results presented in Table 1, the average Z-score determined by the median value for micro agricultural companies in 2019 was 1.44 with large variations, which indicates high heterogeneity within the observed sample. In addition, the results of the Z-score for micro agricultural companies show that these companies, on average, operated in the distress zone, i.e. the zone of insolvency. The average profitability of micro agricultural companies was extremely low, amounting to only 0.51% with considerable variations, as a large number of these companies had negative financial results. The productivity of micro agricultural companies ranged from -15,965 to 23,407 (RSD/employee), and it was also subject to large variability. Small agricultural companies had significantly better results compared to micro companies, with an average Z-score of 2.34, an average profitability of 1.41% and an average productivity of 272.01 (RSD/employee). Compared to micro companies, small agricultural companies were significantly less subject to variability for all observed indicators. Medium-sized agricultural companies had a lower Z-score value than small companies, but they achieved higher average profitability (1.92%) and productivity (514.38 RSD/employee). Large companies had the highest values of all three observed indicators, with the lowest variability. The average value of the Z-score for large agricultural companies was 2.67, which means that these companies operated in the safe zone, i.e. they were not at risk of bankruptcy.

Table 1. Descriptive statistics for agricultural companies.

Size of the company	Variable	Median	Minimum	Maximum	Coefficient of variation (%)
Micro companies	Z-score	1.44	-8155.40	611.89	7716.18
	Profitability	0.51	-53100.00	2451.40	1643.93
	Productivity	101.00	-15965.00	23407.00	2452.32
Small companies	Z-score	2.34	-1.10	2299.40	979.47
	Profitability	1.41	-40.00	30.00	307.61
	Productivity	272.01	-11331.60	208783.00	888.91
Medium-sized companies	Z-score	1.84	-0.80	31.91	150.31
	Profitability	1.92	-70.00	42.00	652.72
	Productivity	514.38	-10690.50	27398.39	371.91
Large companies	Z-score	2.67	1.480	8.22	67.96
	Profitability	3.48	-10.00	20.20	139.32
	Productivity	402.25	-278.21	4764.49	134.57

Source: Author's calculation.

The main indicators of descriptive statistics were also calculated for the observed food companies in Vojvodina for 2019 (Table 2).

The results presented in Table 2 show that the average Z-score determined by the median value for micro food companies in 2019 was 0.92. This value of the Z-score for micro food companies indicates that these companies were at risk of bankruptcy. The average profitability of micro food companies was extremely low, amounting to only 0.66% with large variations. The productivity of micro food companies averaged 81.83 (RSD/employee), and it was also subject to great variability. Small food companies achieved significantly better results than micro companies, with an average Z-score of 2.45, an average profitability of 3.04% and an average productivity of 195.30 (RSD/employee). Compared to micro companies, small food companies showed significantly less variability in all observed indicators. Medium-sized food companies had a Z-score of 2.61, which means that they were close to doing business without the risk of bankruptcy. Compared to small companies, medium-sized companies had slightly lower profitability but higher productivity (265.22 RSD/employee). Large food companies had lower Z-score values compared to small and medium-sized companies, which means that they were more exposed to the risk of bankruptcy. The average value of the Z-score was 2.04, profitability was 4.51%, and productivity averaged 1257.44 (RSD/employee). Table 2 indicates large variations for all observed indicators, also showing that variability declined as the size of the company increased.

Table 2. Descriptive statistics of food companies.

Size of the company	Variable	Median	Minimum	Maximum	Coefficient of variation (%)
Micro companies	Z-score	0.92	-2318.50	2520.22	1898.61
	Profitability	0.66	-277.30	101.00	3235.03
	Productivity	81.83	-16348.00	10914.00	1576.62
Small companies	Z-score	2.45	-0.24	8.06	67.16
	Profitability	3.04	-0.31	0.92	269.49
	Productivity	195.30	-2400.40	9554.00	293.62
Medium-sized companies	Z-score	2.61	-1.64	8.85	75.07
	Profitability	2.58	-0.42	0.19	322.81
	Productivity	265.22	-6248.19	7919.79	457.45
Large companies	Z-score	2.04	0.70	4.67	47.31
	Profitability	4.51	-0.05	0.34	128.81
	Productivity	1257.44	-1988.50	11510.62	171.61

Source: Author’s calculation.

The first step in the analysis is testing the formed regression models as a whole by using variance analysis (ANOVA) for regression (Table 3).

According to the results of analysis of variance for regression for micro agricultural companies, the null hypothesis was rejected, so it has been concluded that the formed model was statistically significant. The same conclusion has been reached for small and large agricultural companies. In contrast, in the case of medium-sized agricultural companies, the null hypothesis of analysis of variance for regression was accepted, so it can be concluded that the model was not statistically significant.

The regression model parameters were evaluated for the observed agricultural companies (Table 4).

Table 3. ANOVA for regression for agricultural companies.

Size of the company	Effect	Sum of squares	df	Mean squares	F	p-value
Micro companies	Regression	15943885	2	7971943	22.25778	0.00000
	Residual	334883609	935	358164		
	Total	350827494	937			
Small companies	Regression	179305	2	89652.38	4.5905097	0.010907
	Residual	5248310	269	19510.45		
	Total	5427615	271			
Medium-sized companies	Regression	45.559	2	22.77927	0.929551	0.0400077
	Residual	1543.858	63	24.50568		
	Total	1589.416	65			
Large companies	Regression	20.30888	2	10.15444	12.24749	0.011832
	Residual	4.14552	5	0.82910		
	Total	24.45440	7			

Source: Author's calculation.

Table 4. Main indicators of the regression model for agricultural companies.

Size of the company	Model	b*	Std. err. of b*	b	Std. err. of b	t	p-value
Micro companies	Intercept			15.81950	19.59426	0.807354	0.419668
	Profitability	0.213133	0.031961	5.32002	0.79778	6.668544	0.00001
	Productivity	0.001750	0.031961	0.00062	0.01140	0.054743	0.956355
Small companies	Intercept			8.5860	8.92171	0.962374	0.336726
	Profitability	0.074042	0.060780	166.86131	136.97455	1.218193	0.224218
	Productivity	0.154281	0.060780	0.00171	0.00070	2.538334	0.011703
Medium-sized companies	Intercept			3.142820	0.631361	4.977847	0.000005
	Profitability	0.157370	0.146361	7.166363	6.665005	1.075222	0.286376
	Productivity	0.020799	0.146361	0.000023	0.000164	0.142110	0.887446
Large companies	Intercept			1.93653	0.442782	4.37356	0.007198
	Profitability	1.072431	0.237054	31.13886	6.883044	4.52400	0.006260
	Productivity	-0.305865	0.237054	-0.00029	0.000225	-1.29027	0.253401

Source: Author's calculation.

Based on the results from Table 4 for micro agricultural companies, the following form of a regression model can be obtained:

$$\hat{Y} = 15,81950 + 5,32002X_1 + 0,00062X_2 + \varepsilon \quad (1)$$

The obtained partial regression coefficients (b) indicate that parameter β_1, which defines the independent variable measuring profitability of the company, was statistically highly significant. This variable had a positive impact, and it can be concluded that when profitability increased by one percent, the value of the Z-score for micro agricultural companies increased by 5.32002. On the other hand, the results of regression analysis indicate that productivity had no statistically significant impact on the risk of bankruptcy for micro agricultural companies.

According to the results of regression analysis for small agricultural companies (Table 4), it is possible to obtain a model of the following form:

$$\hat{Y} = 8{,}5860 + 166{,}86131X_1 + 0{,}00171 + \varepsilon \quad (2)$$

Based on the partial regression coefficients, parameter β_2, which defines the independent variable measuring productivity of the company, was identified as statistically highly significant. This variable had a positive impact, so when productivity increased by one unit of measure (RSD/employee), the value of the Z-score for small agricultural companies increased by 0.00171. The results of regression analysis also indicate that profitability had no statistically significant impact on the risk of bankruptcy for small agricultural companies.

Analysis of variance for regression determined that the model for medium-sized agricultural companies was not statistically significant, as neither productivity nor profitability affected the risk of bankruptcy for medium-sized agricultural companies, as measured by the Altman's Z-score. The indicators of descriptive statistics determined that these companies had lower Z-score values but higher values of productivity and profitability compared to small companies, so the above conclusion is in accordance with the results of descriptive statistics.

Based on the results from Table 4 for large agricultural companies, a model of the following form was obtained:

$$\hat{Y} = 1{,}93653 + 31{,}13886X_1 - 0{,}00029X_2 + \varepsilon \quad (3)$$

The partial regression coefficient (b) indicates that parameter β_1, which defines the independent variable of profitability, was statistically highly significant, which means that the profitability of the company had a statistically significant impact on the risk of bankruptcy for large agricultural companies. Based on the positive sign of this variable, it can be concluded that when profitability increased by one percent, the value of the Z-score of large agricultural companies increased by 31.13886. The results of regression analysis for large agricultural companies also indicate that productivity had no statistically significant impact on the risk of bankruptcy for these companies.

Analysis of variance for regression was also applied to the observed food companies (Table 5).

Table Based on the results of variance analysis for regression, which is used to test models as a whole, it can be concluded that all models formed for food companies were statistically significant, so the null hypothesis was rejected for all companies regardless of the company size category.

The regression model parameters were evaluated for the observed food companies (Table 6).

Based on the results obtained from Table 6 for micro food companies, we can obtain a regression model of the following form:

$$\hat{Y} = 13{,}92058 + 5{,}88897X_1 + 0{,}00976X_2 + \varepsilon \quad (4)$$

The obtained partial regression coefficients (b) indicate high statistical significance of the parameter β_1, which defines the independent variable of the profitability of the company. This variable had a positive sign, so it can be concluded that when profitability increased by one percent, the value of the Z-score for micro agricultural companies increased by 5.888897. On the other hand, the regression analysis results indicate that productivity had no statistically significant impact on the risk of bankruptcy for micro food companies.

5. ANOVA for regression for food companies.

Size of the company	Effect	Sum of squares	df	Mean squares	F	p-value
Micro companies	Regression	4339142	2	2169571	70.35783	0.00000
	Residual	16312371	529	30836		
	Total	20651512	531			
Small companies	Regression	94.5795	2	47.28975	19.57498	0.00000
	Residual	231.9193	96	2.41583		
	Total	326.4988	98			
Medium-sized companies	Regression	34.9771	2	17.48857	3.434149	0.040371
	Residual	244.4423	48	5.09255		
	Total	279.4195	50			
Large companies	Regression	6.45157	2	3.225785	4.203675	0.035526
	Residual	11.51059	15	0.767373		
	Total	17.96216	17			

Source: Author's calculation.

Table 6. Main indicators of the regression model for food companies.

Size of the company	Model	b*	Std. err. of b*	b	Std. err. of b	t	p-value
Micro companies	Intercept			13.92058	7.631999	1.82398	0.068720
	Profitability	0.452934	0.038650	5.88897	0.502517	11.71895	0.00001
	Productivity	0.061752	0.038650	0.00976	0.006111	1.59772	0.110702
Small companies	Intercept			2.366336	0.169123	13.99177	0.00001
	Profitability	0.558260	0.098940	8.095830	1.434819	5.64241	0.00001
	Productivity	-0.043221	0.098940	-0.000048	0.000110	-0.43684	0.663207
Medium-sized companies	Intercept			2.87880	0.332499	8.658084	0.000001
	Profitability	0.475197	0.266229	13.17274	7.380013	1.784921	0.080594
	Productivity	-0.150508	0.266229	-0.00019	0.000339	-0.565334	0.574480
Large companies	Intercept			1.65528	0.278333	5.947113	0.000027
	Profitability	0.890786	0.589135	11.04559	7.305166	1.512024	0.151308
	Productivity	-0.322788	0.589135	-0.00012	0.000225	-0.547902	0.591820

Source: Author's calculation.

Based on the results of the regression analysis for small food companies (Table 4), the model of the following form can be obtained:

$$\hat{Y} = 2{,}366336 + 8{,}095830X_1 - 0{,}000048 + \varepsilon \quad (5)$$

The partial regression coefficients identified parameter β_1 as statistically highly significant. This parameter defines the independent variable, which measures the profitability of the company. As this variable had a positive sign, it means that when profitability increased by one unit of measure (%), the value of the Z-score of small food companies increased by 8.095830. The results of regression analysis also indicated that productivity had no statistically significant impact on the risk of bankruptcy for small food companies.

The results of regression analysis for medium-sized and large food companies showed that none of the analyzed variables had a statistically significant impact on the risk of bankruptcy for the observed companies. This result can also be inferred by analyzing the average values of the observed indicators, as the Z-score was higher while profitability and productivity were significantly lower in medium-sized companies compared to large companies.

Conclusion

This study analyzed the impact of profitability and productivity on the risk of bankruptcy for agricultural and food companies in Vojvodina in 2019. The obtained results point to the following conclusions:

By comparing micro companies from the agricultural and food sectors, it can be concluded that agricultural companies had a higher average Z-score value (1.44>0.92) and higher average productivity (101>81.83), while food companies were more profitable (0.51<0.66). Regression models for micro companies from both sectors indicate that profitability had a statistically significant positive impact on the risk of bankruptcy for the observed companies. The positive impact of profitability on the value of the Z-score means that when profitability increased, the risk of bankruptcy for the observed companies declined.

In the case of small agricultural and food companies, it can be observed that agricultural companies had a lower average value of the Z-score (2.34<2.45) compared to companies from the food sector, which means that companies from the agricultural sector were more exposed to the risk of bankruptcy. Small agricultural companies also had lower profitability (1.41<3.04) but higher productivity (272.01>195.30) than small food companies. The results of the regression model for small agricultural companies identified productivity as a significant factor, while for small food companies, it was profitability. In both models, it was found that the observed independent variables had a positive impact on the dependent variable, which means that when productivity and profitability increased, the value of the Z-score also increased.

By comparing the results of descriptive statistics for medium-sized agricultural and medium-sized food companies, it can be concluded that agricultural companies had a lower average value of the Z-score (1.84<2.61), lower profitability (1.92<2.58), but higher productivity (514.38>265.22) compared to food companies. The results of the regression analysis for medium-sized companies in both sectors showed that the risk of bankruptcy was affected by neither profitability nor productivity. This result can be accounted for by the fact that medium-sized companies achieve good business results, so the used indicators are not crucial for assessing the risk of bankruptcy.

Large companies from both sectors were relatively stable, with a low risk of bankruptcy, as the average Z-score for agricultural companies was 2.67, while the average value of the Z-score for food companies was 2.04. The profitability of large agricultural companies was lower compared to the profitability of food companies of the same size (3.48<4.51). Also, the productivity of large agricultural companies was lower than the productivity of large food companies (402.25<1257.44). The results of the regression analysis indicated that for large agricultural companies, the risk of bankruptcy was statistically significantly and positively affected by profitability. However, for large food companies, the risk of bankruptcy was affected by neither profitability nor productivity.

The results of the performed analysis show that the profitability of the observed agricultural companies increased when the company was larger. Medium-sized agricultural companies had higher productivity compared to large agricultural companies due to the outdated production technology of large agricultural companies. It can be concluded that the profitability of the observed food companies also increased when company size increased, except in the case of medium-sized companies, which had lower profitability compared to small companies. Higher productivity of small companies compared to medium-sized ones can be accounted for by a higher rate of investment in fixed and current assets, as well as the intensification of production. The productivity of food companies increased when the company size was larger, which is certainly the result of investments in more intensive production technology.

Recommendations for further studies based on the results obtained in this paper are to examine other independent variables, i.e. more financial ratios, and to determine their impact on the risk of bankruptcy for agricultural and food companies in Vojvodina.

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UTICAJ RENTABILNOSTI I PRODUKTIVNOSTI NA RIZIK BANKROTSTVA POLJOPRIVREDNH I PREHRAMBENIH PREDUZEĆA U VOJVODINI

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R e z i m e

U radu su analizirana poljoprivredna i prehrambena preduzeća koja su poslovala na području Vojvodine u 2019. godini. Analizom su obuhvaćeni rizik bankrotstva, meren Altmanovim Z-skorom, rentabilnost i produktivnost posmatranih preduzeća. Cilj rada bio je da se na osnovu podele preduzeća po veličini, na mirko, mala, srednja i velika, primenom modela višestruke regresije utvrdi uticaj rentabilnosti i produktivnosti na rizik bankrotstva poljoprivrednih i prehrambenih preduzeća različite veličine, kao i da se uporede rezultati iz ova dva sektora. Na osnovu dobijenih rezultata utvrđeno je da na rizik bankrotstva mikro i velikih poljoprivrednih preduzeća statistički značajan i pozitivan uticaj ima rentabilnost, dok na rizik bankrotstva malih poljoprivrednih preduzeća pozitivan i statistički značajan uticaj ima produktivnost. Na rizik bankrotstva srednjih poljoprivrednih preduzeća ne utiču ispitivani pokazatelji. Regresionom analizom utvrđeno je i da na rizik bankrotstva mikro i malih prehrambenih preduzeća statistički značajan pozitivan uticaj ima rentabilnost, dok na rizik bankrotstva srednjih i velikih prehrambenih preduzeća ne utiču posmatrane promenljive.

Ključne reči: profitabilnost, produktivnost, bankrotstvo, poljoprivreda, prehrambena industrija, Vojvodina.

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ECONOMIES OF SCALE AND TECHNICAL EFFICIENCY OF SMALLHOLDER PEPPER (*CAPSICUM SPECIES*) PRODUCTION IN ABUJA, NIGERIA

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Abstract: This study examined the economies of scale and technical efficiency of smallholder pepper (*Capsicum species*) production in Abuja, Nigeria. The multi-stage sampling technique was adopted to obtain a total sample size of 100 smallholder pepper farmers. The primary sources of data were obtained from pepper farmers through a well-structured and well-designed questionnaire. The data obtained were analysed using descriptive statistics, gross margin model, financial analysis, stochastic production frontier model, the elasticity of production, return to scale, and principal component analysis. The results from the study showed that the mean age of pepper farmers observed was 38.3 years. The average household size was 5 persons. The gross margin was ₦ 167, 741.60 per hectare, the rate of returns of the investment in pepper production amounted to 0.89, and the operating ratio was 0.49. The gross margin ratio (GMR) was calculated to be 0.48, and this implies that for every naira that is invested in smallholder pepper production, 48 kobos would be used to cover profits, interest, expenses, taxes, and depreciation. Labour input ($P < 0.10$), seed input ($P < 0.01$), farm size ($P < 0.01$) were significant factors affecting output of smallholder pepper production. The mean technical efficiency was 0.79, leaving a gap of 0.21 for improvement. The returns to scale of 1.2363 imply increasing returns to scale. The study recommends that measures should be put in place to address the challenges of inadequate rainfall through proper irrigation policies.

Key words: economies of scale, stochastic production frontier model, pepper production, Abuja, Nigeria.

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Introduction

Pepper (*Capsicum species*) is an important agricultural food crop, firstly, because of its economic value and importance, secondly, due to the contents, nutritional and medicinal values of its fruits, as well because of being a good and excellent source of natural colours and anti-oxidant compounds (Horward et al., 2000). Pepper is recognised as the most widely and varied food for general populace in Africa and the entire world (Dipeolu and Akinbode, 2008). It is reported to be the world's most important fruit vegetable, which ranks second after tomatoes. Pepper provides essential minerals, vitamins and is the most widely produced type of spice flavouring and colouring for food (Bosland and Votava, 2000). In Nigeria, three major types of pepper are common: firstly, the large fruited sweet peppers (Tatashe); secondly, the medium corrugated fruited hot pepper (Rodo) and thirdly, the small-fruited with chilli/red pepper (Shombo) (Dipeolu and Akinbode, 2008). Peppers are rich in vitamins A, C and K. Vitamin A is reported to be good for eye sight, and vitamin C also prevents the common cold. All varieties are good and excellent sources of potassium, vitamins A and C, fibre, and folic acid.

Agriculture in a developing African country like Nigeria is dominated largely by smallholder farmers. They are involved in the production of the majority of food requirements like pepper needed for the country (Asogwa et al., 2006). Despite the fact that these smallholder farmers occupy an important and unique vital position, they can be observed to belong to the poorest class or group identified within the population and as such, they cannot invest anything in their farms (Asogwa et al., 2006). Smallholder farmers are reported to be driving force of many economies in Africa, even though their potentials are often not observed and brought forward. Smallholder or small-scale farmers can be defined in various ways depending on the context, region, country, and even ecological zone. Often the term 'smallholder' is sometimes interchanged with 'smallscale', 'marginal' 'peasant' and sometimes 'resource-poor'. Generally, smallholders only refer to their small and limited resource endowment compared to farmers in the other sectors. Smallholder farmers can be defined or explained as those farmers owning or having small-based plots on which they grow family or subsistence crops, and one, two or more cash crops, and they rely mainly on family labour. One of the major characteristics observed of production systems common to smallholder farmers is the fact that they are simple, use outdated technologies, they have low or small returns, and have high seasonal fluctuations in labour requirements. Smallholder or small-scale farmers significantly differ due to their individual or personal characteristics, sizes of farms, resource distributions between cash and food crops, off-farm activities and livestock farming, the way they use external inputs, obtain hired labour, the percentage of food crops sold and their patterns of expenditure on households. According to Ajibefun and Daramola (2003), the vicious cycle of poverty prevailing among these farmers can lead to unimpressive and poor performance of the agricultural sector. Thus, resources must be efficiently used, which entails the total elimination of wastes, thereby leading to an increase in productivity, efficiency, and incomes. Rural farmers in Nigeria are resource-poor, operate on small scale, and lack of credit facilities, which translates to the inadequacy of working capital bringing about the vicious cycle of poverty (Kibaara, 2005). Demand for pepper can be created by both the end consumer, buying the product for their individual or personal food needs or requirements, and the corporate and international markets, that use spicy or pepper products in their production processes. Hotels, catering services and restaurants can be said to be the consumer segment of pepper. Ultimately, the demand for the products will depend largely on the wealth of the people and the population growth that are the end consumers of pepper. Studies on the efficiency and productivity of agricultural production in Nigeria have not focused on pepper despite its important role in the nutrition of the people. In order to achieve self-sufficiency in pepper production, there is an urgent need to assess the efficiency of pepper production.

Objectives of the study

The objective was broadly designed to evaluate the economies of scale and technical efficiency of smallholder pepper (*Capsicum species*) production in Abuja, Nigeria. Specifically, the study was designed to achieve the following objectives to:

(i) identify the socio-economic profiles of smallholder pepper producers;

(ii) estimate the costs and return analysis of smallholder pepper production;

(iii) evaluate factors affecting the output of smallholder pepper production;

(iv) evaluate factors influencing the technical efficiency of smallholder pepper production;

(v) determine the technical efficiency index of smallholder pepper producers;

(vi) determine the elasticity of production and economies of scale of smallholder pepper production, and

(vii) identify the problems or constraints facing smallholder pepper production.

Material and Methods

The study area

The study was carried out in Abaji Area Council in Abuja, Nigeria. The local government is located at latitudes 8.4747° North, and longitudes 6.9451° East.

Abaji is an area Council in the Federal Capital Territory with headquarters in the town of Abaji. Abaji is located north of Kogi State, with Gwagwalada, Kuje and Kwali Area Councils to the east and Niger State bounded to the north and the west. In Abaji, there are wet and dry seasons. The dry seasons are partly cloudy, humid, and hot all year round. The temperature varies from 64ºF to 94ºF and is rarely below 57ºF or above 100ºF. Abaji has a cover land area of about 999km² and a population of 58,642 persons at the 2006 national census (NPC, 2006). The council is the smallest, by population, of the six area councils in Abuja. Abaji Area Council is predominantly inhabited by the Ebira Koto, a sub- group of the larger Ebira ethnic group found in neighbouring Koton Karfe Local Government Area of Kogi State. Economic activities include: trading, animal rearing, food, vegetable and cash crop production. The occupation of the people is farming and they plant yam, maize, pepper, among others (Figure 1).

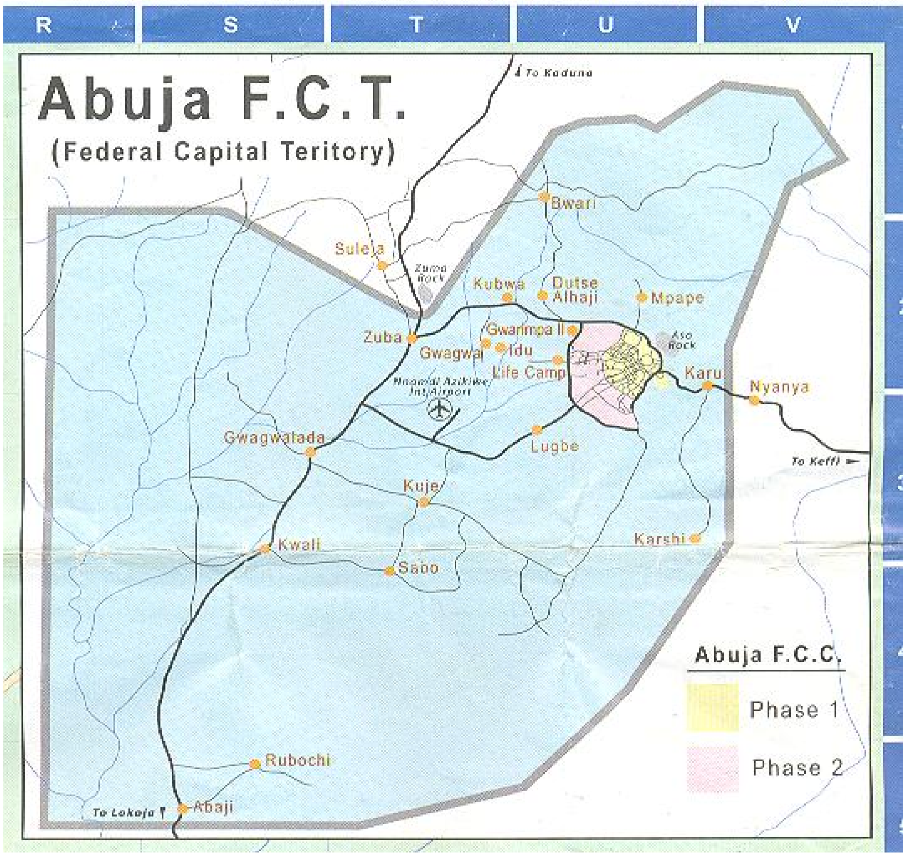

Figure 1. The map of Abuja, showing Abaji Area Council, Nigeria.

The method of data collection

Cross-sectional data from the primary source were collected from smallholder pepper farmers. Data were sourced through the use of a well-structured and, well-designed questionnaire which was administered through the use of personal interactions and interviews. Data were centered on the following: socio-economic profiles of smallholder pepper farmers such as household size, age, farm size, gender, educational level, farming experience, quantities of inputs, the quantity of output and their associated costs, and the value, and the constraints facing smallholder pepper producers.

Sampling techniques and sample size

The multi-stage sampling technique was used to select the sampled respondents, the smallholder pepper producers. In the first (1st) stage, 5 wards out of 10 wards were randomly selected using the ballot-box raffle draw method including Abaji South East, Gawu. Yaba, Nuku and Gurdi. In the second (2nd) stage, 2 villages were randomly selected per ward using the ballot-box raffle draw method making a total of 10 villages. In the third (3rd) stage, 10 smallholder pepper farmers per village were randomly selected using the ballot-box raffle draw method to make a total sample size of 100 smallholder pepper farmers used for the study The purposive sampling method was used to select Abaji Area Council because of the predominant smallholder pepper production in the area.

The method of data analysis

The following statistical or econometric tools were adopted and used for achieving the stated specific and broad objectives: descriptive statistics, gross margin analysis, financial analysis, stochastic frontier model, elasticity of production, return to scale, and principal component analysis.

Descriptive statistics

This includes: - frequency distributions, mean, and percentages. This was used to have a summary statistic of data collected for achieving objectives of identification of the socio-economic profiles or characteristics of smallholder pepper farmers along with identification of constraints or problems faced by smallholder pepper producers.

Gross margin analysis

The gross margin model is stated thus:

$$GM = GI - TVC \quad (1)$$

where,
GM = Gross margin measured in naira,
GI = Gross income measured in naira,
TVC = Total variable cost (naira).

This was used to estimate the costs and returns of smallholder pepper production as stated in specific objective two (ii).

Financial analysis

In order to evaluate the strength and financial positions of smallholder pepper production, operating ratio, rate of return per naira invested, and gross margin ratios were considered. An operating ratio (OR) according to Olukosi and Erhabor (2005) is stated thus:

$$OR = \frac{TVC}{GI} \quad (2)$$

where,
OR= Operating ratio (units),
TVC=Total variable cost (naira),
GI=Gross income (naira).

An operating ratio that is less than one (1) implies that the total revenue obtained from smallholder pepper production was able to offset or pay for the cost of variable inputs used in the enterprise (Olukosi and Erhabor, 2005). The rate of return per naira invested (RoRI) in smallholder pepper production is stated thus:

$$RORI = \frac{NFI}{TC} \quad (3)$$

where,
RORI= Rate of return per naira invested (units),
NFI= Net farm income from pepper production (naira),
TC = Total cost (naira).

The gross margin ratio (GMR) following Ben-Chendo et al. (2015) is stated thus:

$$Gross\ Margin\ Ratio = \frac{Gross\ Margin}{Total\ Revenue} \quad (4)$$

The financial analysis was specifically used to achieve part of objective two (ii) which is to analyze the costs and returns of smallholder pepper production.

Net farm income (NFI) is stated thus:

$$NFI = \sum_{i=1}^{n} P_1 Y_i - \sum_{j=i}^{m} P_j X_j - \sum_{k=1}^{k} GK \quad (5)$$

NFI = Net farm income (naira per ha)

P_i = Unit price of product (naira/ha)
P_j = Price per unit variable input (naira/unit)
GK = Cost of fixed inputs (where k = 1,2,3, ……………. k fixed input)
$\sum$ = Summation (Addition) sign

The stochastic production frontier model

The stochastic production frontier model is stated thus:

$$Y_i = f(X_i, \beta_i)e^{v_i - u_i} \quad (6)$$

$$l_nY = \propto_0 + \beta_1 l_nX_1 + \beta_2 l_nX_2 + \beta_3 l_nX_3 + \beta_4 l_nX_4 + \beta_5 l_nX_5 + V_i - U_i \quad (7)$$

where,
Y_i = Output of pepper (kg)
X_i = Vector of variable inputs
β_i = Vector of estimated parameters
V_i = Error term, random variation in output
U_i = Error term due to technical inefficiency
X_1 = Labour input (mandays)
X_2 = Seed input (kg)
X_3 = Fertilizer input (kg)
X_4 = Chemical input (litre)
X_5 = Farm size (ha)

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 \quad (8)$$

where,
U_i = Error term associated with technical inefficiency
Z_1 = Sex (1, male; 0, otherwise)
Z_2 = Age (Years)
Z_3 = Marital status (1, married; 0, otherwise)
Z_4 = Level of education (0, non-formal; 1, primary; 2, secondary; 3, tertiary)
Z_5 = Household size (number)
Z_6 = Faming experience (years)
Z_7 = Access to extension officers or agents (number of meetings/week)
Z_8 = Access to credit facilities (1, access; 0, otherwise)
δ_0 = Constant term
$\delta_1 = \delta_8$ = Parameters to be estimated

This was specifically used to achieve objectives three (iii), four (iv), five (v), and six (vi)

The elasticity of production and return to scale

Return to scale of the farm operations can either be increasing, decreasing, or constant return to scale based on the value.

$$RTS = \sum EPI_S \quad (9)$$

where,
RTS = Returns to scale, and
EPI_S = Elasticity of production inputs (units)
This was used to achieve specific objective six (vi)

Principal component analysis (PCA)

The perceived constraints faced by smallholder pepper production were analyzed using principal component analysis (PCA). The model of principal component analysis (PCA) is stated thus:

$$x = x_1, x_2, x_3, \dots, x_p \quad (10)$$

$$\propto_k = \propto_{1k1}, \propto_2 K, \propto_3 k, \dots, \propto pk \dots \quad (11)$$

$$\propto_K^T x = \sum_{j=1}^{p} \propto_{KjXj} \quad (12)$$

$$Var = [\propto_K^T X] \; is \; Maximum \quad (13)$$

Subject to

$$\propto_K^T \propto_K = 1 \quad (14)$$

$$\text{and Cov} = [\propto_1^T \propto - \propto_2^T \propto] = 0 \quad (15)$$

The variances of each of the principal component are:

$$Var[\propto_k X] = \lambda_k \quad (16)$$

$$S = \frac{1}{n-1}(X - \bar{X})(X - \bar{X})^T \quad (17)$$

$$S_i = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X}_i)\,(X_I - \bar{X}_i) \quad (18)$$

where,
X = Vector of ‘P’ random variables
$\propto_k$ = Vector of ‘P’ constraints
λ_k= Eigen value
T = Transpose
S = Sample covariance matrix
This was used to achieve specific objective six (vi)

Results and Discussion

Socio-economic profiles of smallholder pepper farmers

Table 1 shows the result obtained on the socio-economic profiles of the smallholder pepper farmers. From the result, about 82 % of the smallholder pepper farmers were between 31 and 50 years of age. This means that most pepper farmers were predominantly in their economically active age, with a mean age of 38.3 years. Pepper production has great potential for reducing the poverty level among the populace and as well serves as a food security crop. This result agrees or in line with the findings of Alabi et al. (2013), Mohammed et al. (2016) who stressed that farmers within the ages of 31-50 years were relatively young and are within the energetic and active age in pepper production, thus productivity might be high. Educated young farmers'- gains more experiences and acquaint themselves with new technologies and are expected to adopt and use new technologies more efficiently.

Table 1. The socio-economic profiles of the smallholder pepper producers.

Variables			
Age (years)	Frequency	Percentage	Mean
< 30	18	18.0	
31 – 40	45	45.0	38.3
41 – 50	37	37.0	
Gender			
Male	80	80.0	
Female	20	20.0	
Marital status			
Single	17	17.0	
Married	74	74.0	
Divorced	04	04.0	
Widow/Widower	03	03.0	
Educational status			
Primary	18	18.0	
Secondary	13	13.0	
Tertiary	22	22.0	
Non-formal	47	47.0	
Occupation			
Farmer	94	94.0	
Formally employed	02	02.0	
Business	04	04.0	

Source: Field survey (2019).

About 80% of the pepper farmers were male, while 20% were female. The percentage of male to female pepper farmers indicates that pepper farming activities were gender-sensitive. This finding or result is in agreement with the findings of Alabi et al. (2014). The majority (74.0%) of the smallholder pepper farmers were married. This result is in agreement with those of Alabi (2012), Adeoye et al. (2014), who reported that family members serve as a readily available source of the farm labour force. About 53% of smallholder pepper producers had formal education, while 47% had non-formal education. Education enhances their responses in adopting innovations and new technologies. This agrees with Alabi et al. (2009), and Alabi et al. (2010a), who have reported that education acquired is an important factor influencing management and the adoption of new technology. The majority of the smallholder pepper farmers had household sizes between 6 to 10 persons. The mean household size was 5 people per household. This has direct implications on labour supply to the farm because of the potential contributions to labour available for pepper production. The results agree with Sani et al. (2010) who reported that larger household sizes were observed to provide enough persons for family labour which means less or little money will be needed to pay for hired labour.

Table 1 (continued). The socio-economic profiles of the smallholder pepper producers.

Household size (units)			
≤ 5	35	35.0	
6 – 10	62	62.0	5.34
≥ 11	03	03.0	
Access to credit			
Yes	52	52.0	
No	48	48.0	
Extension contact			
Yes	70	70.0	
No	30	30.0	
Years of experience			
< 5	74	74.0	
6 – 10	23	23.0	4.7
11 – 15	03	03.0	
Member of cooperative			
Yes	74	73.0	
No	27	27.0	
Farm size (hectare)			
.50	18	18.0	
1.00	33	33.0	
1.50	06	06.0	
2.00	33	33.0	
3.00	06	06.0	
4.00	02	02.0	
5.00	02	02.0	
TOTAL	100	100.0	

Source: Field survey (2019).

Furthermore, 52% of smallholder pepper farmers had no access to credit. This implies that the smallholder pepper farmers may have to finance all their operating costs by themselves. This result indicates that agricultural loans were not easily accessible to smallholder pepper farmers. The high-interest rate charged by the commercial and other lending agencies in the country plus cumbersome administrative procedures could be related to poor access to credit (Ume et al., 2010). This agrees with Alabi and Ajooku (2012), Ume and Ochiaka (2016), who reported that the majority of the sampled households do not have any access to credit facilities. The overwhelming majority, 97.5% of the smallholder pepper farmers, had less than 10 years of experience in pepper production. According to Olaoye et al. (2013), the number of years of experience could improve skills and better approaches to farming practices. Experience can help correct past errors and expand or contract the scales of the application of tested skills. Also, respondents with longer or many years of experience could be able to forecast future market situations in which they dispose of their products at higher prices to make better profits. This means that the smallholder pepper production in the study should be able to make relatively sound decisions regarding resource allocation and management of their farms. Table 1 reveals that 73% of sampled smallholder pepper farmers belonged to some form of cooperative society while 27% of the smallholder pepper farmers did not belong to any cooperative society. The membership of cooperative society affords the pepper farmers the opportunity of obtaining credit facilities, sharing information on modern production techniques, purchasing inputs in bulk and exchanging labour. The land is the most important input for agricultural production. Nigerian farms are classified into small-scale, medium-scale and large-scale. Farm sizes of less than 5 hectares are classified as small-scale, between 5 and 10 hectares as medium-scale, and more than 10 hectares as large-scale. Most pepper farmers (Table 1) had less than 5 hectares, hence, they are classified as small-scale farmers.

Costs and return analysis of smallholder pepper production

Table 2 shows the estimated costs and returns analysis of smallholder pepper production in Abaji Area Council, Abuja, Nigeria. The total revenue is the same value as gross income in this study and was calculated to be ₦348, 719.00. The total cost was ₦180, 977.40 which is a sum of the total variable cost (TVC) and the total fixed cost, which is the total sum of the total input costs, total labour costs, and rent on land. The gross margin was calculated to be ₦167,741.60. The net farm income (NFI) was calculated to be ₦160, 642.69. The rate of return on investment was 2.17. This means that smallholder pepper production was profitable. The total variable cost was 96.07% of the total cost. The total input cost was ₦55, 781.30, which makes up 30.8% of the total cost, on the other hand the total labour cost, was ₦78, 096.99, which results into 43.15% of the total cost. The operating ratio was 0.49, and the gross margin ratio was 0.481, which implies that for every naira invested in smallholder pepper production, 48 kobos would be used to cover profits, taxes, expenses, and depreciation. These findings are in agreement with Alabi and Ajooku (2012), Adeniyi et al. (2015); Edet et al. (2016); Njoku and Offor (2016).

Table 2. The average costs and returns of smallholder pepper production per hectare.

Items (annual)	Amounts (₦)	%of Total cost
Total revenue/ Gross income…. (A)	348, 719.00	
Input costs		
Seeds	16, 200	
Herbicides	4,908.51	
Fertilizers	20,829.79	
Insecticides	5,761.70	
Bags/Sacks	4,819.14	
Manure	3,262.16	
Total input cost………………. (B)	55,781.30	30.8
Labour costs		
Land clearing	8,597.87	
Soil tillage	13, 379.79	
Planting	7, 807.38	
Manure application	2,709.57	
Chemical application	4, 397.87	
Weeding	8, 973.40	
Fertilizer application	3,707.87	
Harvesting	12,975	
Bagging	4, 305	
Transportation	4, 373.80	
Storage	2, 844.44	
Loading	4, 025	
Total labour cost …………... (C)	78,096.99	43.15
Rent on land ……………….(D)	40,000	
Total variable costs (B+C+D) …… (E)	173,878.29	96.07
Fixed cost		
Hoe	2, 985.19	
Cutlass	1,629.63	
Radio	2, 484.29	
Total fixed cost (depreciated and interest) …… (F)	7,099.11	
Total cost (E+F)	180, 977.40	
GM (A-E)	167, 741.60	
NFI (GM-F)	160,642.49	
OR	0.49	
RORI	0.89	
GMR	0.481	

Source: Field survey (2019).

The technical efficiency index of smallholder pepper farmers

Table 3 shows the result of the stochastic frontier production model function of smallholder pepper farmers. Labour input ($P<0.10$), seed input ($P<0.01$), farm size ($P<0.01$) were significant factors influencing the output of smallholder pepper production.

This implies that a 1% increase in the labour inputs holding other factors or variables constant will lead to about a 6.26% increase in the quantity of pepper produced. This result is in line with the findings of Alabi et al. (2010b), and Kasim et al. (2014). Seed input was significant and positive at the 1% probability level, which means that a 1% increase in the quantity of seed input used, holding other factors or variables constant, will lead to about a 32.14% increase in the quantity of pepper produced. The elasticity of production for seed input equalled 0.32 indicating the inelasticity of seeds in the production process. This is in line with the findings of Idris et al. (2015) and Alabi et al. (2010a).

A 1% increase in the farm size holding other variables constant, will lead to about a 69.85% increase in the quantity of pepper produced. Farm size had the highest elasticity, which was 0.69. The variance parameters estimated in the production model represented by sigma-squared (δ^2) were statistically significant at the 5% probability level. This signifies a good fit for the model estimated and the correctness of the distributional assumptions for both the U_i and the V_i which implies that a greater part of the residual variations in output is linked with technical inefficiency rather than with measurement errors which can be said to be linked with uncontrollable factors associated with the production process (Omonona et al., 2010). Based on the value of lambda (λ), we can derive gamma (γ). This means the effect of the technical efficiency in the variations of the observed output from the estimated gamma was 0.59, implying that 59% of variations in the smallholder pepper output were due to technical efficiency. The return to scale was 1.2363, indicating an increase in return to scale. The inefficiency model shows that the educational status or level attained ($P<0.05$), household or family size ($P<0.01$), and access to extension agents ($P<0.01$) were statistically significant. A unit increase in the educational level will lead to about a 0.45 unit decrease in technical inefficiency suggesting that as farmers acquire education, they will gain technical knowhow, develop mastery of resource allocations, and become more technically efficient. As farmers acquire education, it could lead to an increase in the adoption of improved technology and production techniques. Onumah et al. (2010) have noted that formal education enlightens pepper farmers about the technical aspect of production, enhancing efficiency and productivity. One-unit increment in the number of the household members involved in pepper production will lead to a 0.38 unit decrease in technical inefficiency. This result agrees with the findings of Abdulakeem et al. (2019), Ajani and Olayemi (2011).

Table 3. The stochastic production frontier function for the smallholder pepper farmers.

Variables	Coefficient	Standard error	Z-score
Labour input (X_1)	0.0626	0.0357	1.78*
Seed input (X_2)	0.3214	0.0975	3.4***
Fertilizer input (X_3)	0.1003	0.0665	1.51
Chemical input (X_4)	0.0535	0.0632	0.85
Farm size (X_5)	0.6985	0.1118	6.39***
Constant	6.2121	0.2295	27.07
Inefficiency model			
Sex (Z_1)	-0.0964	0.4992	-0.19
Age (Z_2)	0.0241	0.0322	0.75
Marital status (Z_3)	0.1116	0.7031	0.16
Level of education (Z_4)	-0.4480	0.2215	-2.04**
Household size (Z_5)	-0.3875	0.1201	-3.24***
Farming experience (Z_6)	0.0006	0.0268	0.02
Access to extension agents (Z_7)	2.1275	0.6291	3.38***
Access to credit (Z_8)	2.1476	1.5241	1.41
Return to scale	1.2363		
Lambda (λ)	1.2120		
Sigma- squared (δ^2)	0.2502**		
Gamma (γ)	0.59016		

Source: Field survey (2019). *-Significant at 10% probability level; ** -Significant at 5% probability level, and ***- Significant at 1% probability level.

Distribution of technical efficiency of smallholder pepper farmers

Table 4 shows the distribution of smallholder pepper farmers at the different efficiency levels. The majority (32%) of the smallholder pepper farmers were between 71% and 80% efficiency levels implying that most farmers were technically efficient. Such efficiency distribution conforms to previous studies carried out by Alabi et al. (2010b), Alabi et al.(2010a), Ekunwe and Emokaro (2009); and Alawode and Jinad (2014), who pointed out that the technical efficiency index of pepper farmers was 79.7%, leaving a gap of 20.3% for improvement. The minimum technical efficiency was 31.5%, while the best performing farm had the maximum technical efficiency of 98.6%. If the average pepper farmers were to achieve the level of technical efficiency like most of its efficient counterparts, then the average pepper farmer could make 19.16% cost savings [1 – (79.7/98.6) x 100]. The estimates for the most technically inefficient farmer reveal a cost saving of 68.05% [1 – (31.5/98.6) x 100].

Table 4. The descriptive statistics of technical efficiency.

Efficiency score	Freq.	Percent	Cum.
0.00 – 0.49	03	03.0	03.00
0.51 – 0.60	05	05.00	08.00
0.61 – 0.70	15	15.00	23.00
0.71 – 0.80	32	32.00	55.00
0.81 – 0.90	22	22.00	77.00
0.91 – 1.00	23	23.00	100
Total	100	100	
Mean	0.7974286		
Standard deviation	0.1220531		
Minimum	0.3150281		
Maximum	0.9862165		

Source: Field survey (2019).

The principal component analysis of constraints facing smallholder pepper farmers

Table 5 shows the results of the constraints faced by smallholder pepper farmers. Principal component analysis (PCA) is reported to be a statistical technique that transforms interrelated data with many variables into few numbers of uncorrelated variables. The results shows that the number of principal components retained using the Kaiser Meyer criterion was nine based on the Eigen value greater than 1. The retained components explained 70.32% of the variations of the component included in the model. Kaiser-Meyer-Olkin (KMO), which measures sampling adequacy, gave an estimated value of 0.53, and the chi-square observed to be 560.260 was statistically significant at the 1 % level of probability. This demonstrated the feasibility of using the data set for factor analysis. The use of crude implements had an Eigen-value of 3.2351 and it ranked 1st in the order of importance based on the perceptions of the smallholder pepper farmers. The lack of fertilizers and improved seeds with Eigen-values of 2.31613 and 2.22658 ranked 2nd and 3rd, respectively. This is based on the order of occurrences and perceptions of the smallholder pepper farmers as the major constraints facing pepper farmers. Bad road infrastructure, pests, disease insurgence and infestation, and lack of credit facilities with Eigen-values of 1.84691, 1.7184 and 1.43801 follow the same order of their occurrences and importance respectively based on the perceptions of smallholder pepper farmers as other challenges faced by smallholder pepper farmers.

Table 5. Results of the principal component analysis of constraints facing smallholder pepper farmers.

Component mean (Std Dev)	Eigen value	Difference	Proportion	Cumulative
Crude implements	3.235	0.918974	0.1407	0.1407
Lack of fertilizers	2.3161	0.0895476	0.1007	0.2414
Lack of improved seeds	2.22658	0.379674	0.0968	0.3382
Bad road infrastructure	1.84691	0.128506	0.0803	0.4185
Pest and diseases infestation	1.7184	0.280386	0.0747	0.4932
Lack of credit facilities	1.43801	0.179065	0.0625	0.5557
Lack of extension services	1.25895	0.158646	0.0547	0.6104
Lack of access to farm land	1.1003	0.06629	0.0478	0.6583
Lack of iinformation	1.03401	0.137515	0.0450	0.7032
Bartlett test of sphericity				
Chi-square	560.260***			
Rho	1.0000			
KMO	0.5262			

Source: Field survey (2019).

Conclusion

Based on the findings from of this study, it can be concluded that smallholder pepper farmers were young, energetic, and resourceful with a mean age of 38.3 years. The household or family sizes were large, with an average of 5 people per household, having considerable experience in pepper farming, with an average experience of 4.7 years. Pepper farming is a profitable enterprise with a gross margin and the net farm income of 167,741.60 nairas and 160,642.69 nairas respectively. The gross margin ratio of 0.481 revealed that for every naira incurred or invested in pepper enterprise, 0.48 covered expenses, taxes, interest, profits, and depreciation. Labour input, seed input, and farm size were positive and statistically significant factors affecting the productivity of smallholder pepper production. The level of education attainment, household or family size, and access to extension agents were statistically significant factors in the technical inefficiency model, and the technical efficiency index was 79.7%, leaving a gap of 20.3% for improvement. The elasticity of production for seed input was inelastic. The return to scale for smallholder pepper production was increasing return to scale. Major constraints faced by smallholder pepper farmers were the use of crude implements, lack of fertilizers, lack of improved seeds, bad roads, lack of credit facilities, lack of access to farm land, lack of extension services, pest and disease infestation, and lack of information based on the perceptions of smallholder pepper farmers.

The following were policy recommendations basically arising from the findings of this study:

(i) Extension officers should be employed to disseminate research findings to smallholder pepper farmers. Extension agents will effectively mobilize rural farmers for full participation in the production of pepper through the use of community leaders in the study area.

(ii) Farm inputs such as fertilizers, improved seeds, and credit facilities should be provided and made available to smallholder pepper farmers to boost their production by increasing their efficiency.

(iii) Farm land with irrigation facilities should be made available to farmers to encourage them to increase pepper production.

(iv) Feeder roads should be constructed to evacuate produce from farms to market centres along with transportation facilities to provide easy transportation of farm produce to nearby market centres to avoid spoilage and bruises to farm produce.

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EKONOMIJA OBIMA I TEHNIČKA EFIKASNOST MALIH GAZDINSTAVA USMERENIH NA PROIZVODNJU PAPRIKE (*CAPSICUM SPECIES*) U ABUDŽI (NIGERIJA)

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R e z i m e

Ovim istraživanjem se ispituje ekonomija obima i tehnička efikasnost malih gazdinstava usmerenih na proizvodnju paprike (*Capsicum species*) u Abudži (Nigerija). Tehnika višeetapnog uzorkovanja je usvojena da bi se dobila ukupna veličina uzorka od 100 malih poljoprivrednih proizvođača paprike. Primarni izvori podataka dobijeni su od proizvođača paprike putem dobro struktuiranog i dobro osmišljenog upitnika. Dobijeni podaci su analizirani korišćenjem deskriptivne statistike, bruto marže, finansijske analize, modela stohastičke granice funkcije proizvodnje, elastičnosti proizvodnje, povraćaja u odnosu na obim i analize glavnih komponenti. Rezultati studije su pokazali da je prosečna starost posmatranih proizvođača paprike bila 38,3 godine. Prosečna veličina domaćinstva bila je 5 osoba. Bruto marža iznosila je ₦ 167.741,60 po hektaru, stopa povraćaja investicije u proizvodnju paprike 0,89, a koeficijent poslovanja 0,49. Koeficijent bruto marže je izračunat na 0,48, a to implicira da bi se za svaku nairu koja je uložena u proizvodnju paprike malih gazdinstava, 48 koboa koristilo za pokrivanje profita, kamata, troškova, poreza i amortizacije. Uloženi rad ($P < 0,10$), uloženo seme ($P < 0,01$), veličina farme ($P < 0,01$) bili su značajni faktori koji su uticali na proizvodnju paprike na malim gazdinstvima. Srednja tehnička efikasnost bila je 0,79, ostavljajući prostora od 0,21 za poboljšanje. Povraćaj u odnosu na obim od 1,2363 implicira povećanje povraćaja u odnosu na obim. Ovim istraživanjem preporučuje se uvođenje mera za rešavanje izazova neadekvatnih padavina kroz odgovarajuće pristupe navodnjavanju.

Ključne reči: ekonomija obima, model stohastičke granice funkcije proizvodnje, proizvodnja paprike, Abudža, Nigerija.

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THE NEXUS BETWEEN AGRICULTURAL LOAN ACCESS AND FARM INCOME OF SMALL-SCALE CASSAVA PROCESSORS IN OYO STATE, NIGERIA: AN ENDOGENOUS SWITCHING REGRESSION APPROACH

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Abstract: An agricultural loan is an essential tool for transforming commercial agriculture into a profitable venture. In view of this, this study investigated determinants of access to agricultural loans and the profitability of small-scale cassava processing. It also tested whether access to agricultural loans affected the net farm income of cassava processors in Oyo State using budgetary analysis, endogenous switching regression model (ESRM) and augmented inverse probability weighted regression adjustment (AIPWRA) as a robustness check. A multistage random sampling procedure was employed to gather information from 120 cassava processors. The results revealed that female processors dominated cassava processing, and processors had a mean age of 41.1±7.5 years. Only 23% of the respondents had agricultural loan access, which was primarily sourced informally. Budgetary analysis showed that processors earned an average net farm income of ₦10,449.87 (US$29.03) in a production cycle. Endogenous switching regression analysis revealed that married and educated cassava processors that were socially inclusive and that had a large processing unit and earned meagre off-farm income were more likely to access agricultural loans. Furthermore, education (β=0.019, p<0.1), number of family members working (β=0.241, p<0.01), processors' experience (β=0.028, p<0.05) and enterprise size (β=0.001, p<0.01) influenced the net farm income of processors that had access to agricultural loans. The treatment effect from the AIPWRA result revealed that ATT and POM for cassava processing were 4.5% and 37%, respectively. Business risks, small enterprise size and high interest rate were the major constraints to agricultural loan access. From the foregoing, a need for a technical support system among cassava processors is inevitable. More so, cassava processors should be encouraged to join trade associations, and young processors should be given priority in credit initiatives for cassava processing.

Key words: farm credit, loan policy, smallholder, cassava processing, profitability, ESRM, AIPWRA.

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Introduction

Cassava (*Manihot esculenta*) is the most important staple crop in Nigeria, followed by maize, sorghum, millet and yam (FAOSTAT, 2019). Cassava is not just a food crop but also a major source of income for producing households and the country at large. As a classic food security crop in Nigeria, cassava generates income for the largest number of households in comparison to other staples, produces tubers of high yield under poor conditions, and contributes significantly to poverty alleviation (Nweke, 2003).

Food and Agriculture Organization report has shown that Nigeria is the world's largest producer of cassava, accounting for about 20.3% (59 million tonnes) of global tuberous cassava root (FAOSTAT, 2019). This is not far-fetched as Nigeria is said to put more than 6 million hectares, representing 25.9% of its total land hectarage, into the cultivation of cassava with a yield of 8.76 tonnes per hectare (FAOSTAT, 2019). According to Nweke (2003), more than 90% of the cassava produced in Nigeria is processed into food, nevertheless, a significant proportion goes into industrial use consisting of a major derivative of High Quality Cassava Flour (HQCF), while less than 1% is exported. The competing need for the processed form of cassava for food over the fresh one has diverted efforts of farmers and processors into cassava processing where 70% of the roots are processed into gari while the remaining portion is used for elubo/lafun, abacha, fufu/akpu among others (Abass et al., 2013).

Cassava processing in Nigeria can be categorized into five-level capacities, namely household (or cottage), micro, small, medium and large scales, of which small and medium-level processing operations are dominant. A study by Adekanye et al. (2013) highlighted the lack of funds, high cost of machines, high operational costs and erratic power supply as the major constraints to the mechanization of cassava processing in Nigeria. Incidentally, access to agricultural loan facilities will, in the meantime, proffer the needed solution to the challenges facing the cassava processing enterprise in Nigeria.

The agricultural loan is a cash-based investment capital (credit) issued by the agricultural financial institutions to farmers with or without interest payment, within a specified period, terms and conditions (Kayani et al., 2017). In most developing countries, including Nigeria, the lack of loan facilities is an important constraint facing cassava processors when efforts are made to improve farm performance and living conditions (Oyelade et al., 2019). Several factors have been highlighted to influence access to credit among farmers (Oluwasola, 2009; Ololade and Olagunju, 2013; Kiplimo et al., 2015; Adeyonu et al., 2017; Tanimonure et al., 2020). There is evidence that having access to agricultural loan can boost farm performance significantly (Awotide et al., 2015; Oyelade et al., 2019). Furthermore, the lack of access to loan services due to farmers' attributes coupled with the reluctance of financial institutions to issue agricultural loans had adversely inhibited the capital investment capacity of the cassava industry in Nigeria (Adegbite, 2009; Ololade and Olagunju, 2013), causing difficulties in the use of improved processing inputs and technological adaptive capability, and hence, the decline in cassava productivity and profitability (Adekanye et al., 2013; Oyelade et al., 2019). There is a high expectation that a farmer that has access to loan facilities will be in a vantage position to improve his/her operation, use improved implements, seeds, livestock, manpower, transportation and markets for the sales of output and the purchase of inputs at good market prices (Dzadze et al., 2012). However, having access to loans may not necessarily result in improved welfare outcomes if such loan is not used efficiently (Ololade and Olagunju, 2013; Tran, 2014).

Access to agricultural loans is an unabated problem facing the cassava industry in Nigeria. In a bid to reform the agricultural financing after years of benign neglect, the Nigeria Agricultural Promotion Policy in 2016 made a renewed effort to facilitate group access to loans through farm-based organizations; the aim is to access funds as farmers' group from the Bank of Industry, the Bank of Agriculture, and the Anchor Borrowers' Scheme (Dzadze et al., 2012). However, there is a long-standing debate that the Nigerian cassava industry is yet to benefit optimally from the new agricultural credit policy in spite of the advances made in broadening farmers' loan access (Kuye, 2015; Abass et al., 2013) and smallholder cassava processors still do not have sufficient access to affordable agricultural loan (Kuye, 2015; Ololade and Olagunju, 2013; Dzadze et al., 2012). In seeking explanations for loan behaviour of smallholder farmers in the cassava processing industry, the study intends to assess the profitability of small-scale cassava processing; determine factors influencing access to loans among small-scale cassava processors; evaluate the marginal effect of access to agricultural loans on the net farm income of small-scale cassava processors; analyze the effect of access to agricultural loans on the net farm income of cassava processors; and identify constraints facing cassava processors in accessing agricultural loans in Oyo State.

Materials and Methods

Study area: The study was carried out in Oyo State, which is located in the South-Western region of Nigeria. The State lies between longitude $3^0 38^1$ and $5^0 35^1$ East and latitude $6^0 54^1$ and $8^0\ 37^1$ North of Greenwich meridian, covering approximately an area of 27,648km^2 with a population of 7,840,900 as projected by the national population commission (City Population, 2021). The State is bounded in the north by Kwara State, in the east by Osun State, in the south by Ogun State, and in the west by the Republic of Benin. It has an equatorial climate with dry and wet seasons and relatively high humidity. The wet season lasts from November to

March, while the wet season starts in April and ends in October. Average daily temperature ranges between 25^0C and 35^0C almost throughout the year. Agriculture is the main occupation of the people of Oyo State. The climatic condition of the area is favourable for cassava cultivation and processing.

Data collection and sampling techniques: A multi-stage sampling procedure was adopted to obtain the data for this study. At the first stage, three Local Government Areas (LGAs) with a high prevalence of cassava processing were purposively selected. These included: Egbeda, Ogo-Oluwa and Oyo North LGAs. At the second stage, four towns from each of the selected Local Government Areas (LGAs) were purposively selected based on the high population of cassava processors in the area according to records of the Oyo State Agricultural Development Programme on cassava processing. The third stage involved the snowball selection of 15 processors from each of the selected towns to make a total of 135 respondents. However, a total of 120 respondents had meaningful information needed to achieve the objectives of this study.

Source and type of data: Within the use of a well-structured questionnaire, arrays of information were elicited on farmers' personal attributes such as the age of processors, marital status, education level, extension contact, membership of trade associations, and off-farm income. Features of agricultural loans such as access, frequency, amount and source of loans acquired as well as information on cassava processing activities including the size of the firm, quantity processed, processing costs and revenues from cassava processing, were also gathered. To validate the reliability of the questionnaire, an initial pilot survey of 15 cassava processors was carried out in the Mokola area of Oyo State. Then, the information obtained with the instrument was tested for internal reliability using Cronbach's alpha test, and the result gave a satisfactory coefficient (Cronbach alpha>0.60). This instrument was then applied to survey the entire respondents. Data obtained were analyzed with descriptive statistics, budgetary analysis, endogenous switching regression model (ESRM) and augmented inverse probability weighted regression adjustment (AIPWRA).

The treatment effect model: the endogenous switching regression model (ESRM)

This study employed ESRM propounded by Lokshin and Sajaia (2004) to analyze the income effects of access to agricultural loans in cassava processing. The use of ESRM in assessing the impact of credit on household economics has been studied by Omodara et al. (2021), Ojo and Baiyegunhi (2020), Bidzakin et al. (2019), Lin et al. (2019), and Ojo et al. (2019). ESRM has merits over other treatment effect models due to the robustness to address endogeneity and heterogeneity biases associated with non-randomized, quasi-experimental studies using a simultaneous full information maximum likelihood (FIML) estimator. Further, ESRM estimates the economic implications of a policy variable on the treated and untreated observations independently, taking cognizance of unobserved benefits accrued to beneficiaries of target innovations. In addition, with the use of ESRM, the likely spillover effects and interference arising from similar initiatives are addressed to generate unbiased parameter estimates (Omodara et al., 2021; Ojo et al., 2019; Lokshin and Sajaia, 2004).

Following Baiyegunhi et al. (2010) and Lin et al. (2019), the welfare functions of having access to the agricultural loan facility by a household are given as two-regime equations representing a selection model (a decision to access agricultural loans) and an outcome model (the economic implication of access to loans, i.e. net farm income).

$$Y_{1I}^{*} = d_1 X_{1i} + e_{1i} \; if \; CA_i = 1$$
$$Y_{0I}^{*} = d_0 X_{0i} + e_{0i} \; if \; CA_i = 0 \quad (1)$$

where Y_{1I}^{*} *and* Y_{0I}^{*} stand for the performance indicator (net farm income) of a household that had access to the agricultural loan facility and those that lacked access, respectively; X_{1i} is the vector of i[th] observable households' socio-economic attributes; the vector of the parameter estimates are d_0 and d_1; e_{1i} and e_{0i} are the disturbance terms while CA_i indicates the agricultural loan access status of the household. This welfare function is constrained by a number of factors. In the case of cassava processing households, the agricultural loan access constraints facing cassava processors are, therefore, defined by

$$CA_I^{*} = \gamma Z_i + u_i, \quad CA_I = 1[CA_I^{*} > 0], or CA_I = 0[CA_I^{*} < 0] \quad (2)$$

Z is the vector of cassava processor's socio-economic and farm characteristics, u_i is an error term, γ is the parameter to be estimated.

According to Tran (2014) and Lokshin and Sajaia (2004), the u_i, e_{1i} and e_{0i} are assumed to have a trivariate normal distribution with zero mean and covariance of

$$Cov(e_{0i}, e_{1i}, \text{and } u) = \Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{01} & \sigma_{1u} \\ \sigma_{10} & \sigma_0^2 & \sigma_{0u} \\ \sigma_{1u} & \sigma_{0u} & \sigma_u^2 \end{bmatrix}, \quad (3)$$

var $(u_i) = s_u^2$, var $(e_{1i}) = s_1^2$, var $(e_{0i}) = s_0^2$, cov (e_{1i}, e_{0i}) = undefined due to non-simultaneity in observation of Y_{1i} and Y_{0i}. Consequently, a full information maximum likelihood estimator is suitable to estimate the selection (1) and outcome (2) equations simultaneously. Given the assumption of normal distribution of the error terms, the likelihood function for ESRM is

$$\ln L_i = \sum_1 I_i \omega_i [\ln\{F(\emptyset_{1i})\} + \ln\{f(e_{1i}/\sigma_1)/\sigma_1\}] + (1 - I_i)\omega_i [\ln\{1 - F\}(\emptyset_{0i})\} + \ln\{f(e_{0i}/\sigma_0)/\sigma_0\}] \quad (4)$$

where F is a cumulative normal distribution function, f is a normal density distribution function, ω_i is an optional weight for cassava processor *i*, and

$$\emptyset_{1i} = \frac{(\gamma Z_i + \rho_j e_{ji}/\sigma_1)}{\sqrt{1-\rho_j{}^2}} j = 0,1 \quad (5)$$

where$\emptyset_{1i}$ is the inverse Mills' ratio accounting for the selectivity bias in the sample, $\rho_1 = \sigma_{1u}{}^2/\sigma_1\sigma_u$ is the correlation coefficient between errors in the selection model e_{1i} and the outcome model u_i. Similarly, $\rho_0 = \sigma_{0u}{}^2/\sigma_0\sigma_u$ is the correlation coefficient between e_{0i} and u_i respectively.

ESRM is a 2-step procedure that employs probit and OLS regression models simultaneously to estimate determinants of agricultural loan access and the marginal effect of loan access on the net farm income of cassava processors, respectively. The model is specified as

$$Y_{i=}\delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_4 X_4 + \delta_5 X_5 + \delta_6 X_6 + \delta_7 X_7 + \delta_8 X_8 + u_i,$$
$$\text{s}(D_i = \gamma_0 + \gamma_1 Z_1 + \gamma_2 Z_2 + \delta_3 Z_3 + \gamma_4 Z_4 + \gamma_5 Z_5 + e_i) \quad (6)$$

where Y_i = NFI; D_i = LOANACES; X_1 =AGE; X_2 =GENDER; X_3 =EDU, X_4 =FAMSZ; X_5 =OCCUP; X_6 =WORKHH; X_7 =EXP; X_8 =ENT_SIZE; Z_1 =OFFINC; Z_2 = MARSTAT; Z_3 =LOANPOLICY; Z_4 =EXT_VISIT; Z_5=ASS_MEM, s=selection command

The treatment effect of agricultural loan access on net farm income is then estimated following Lokshin and Sajaia (2004) approach. This treatment and heterogeneity effects are presented in Table 1.

Table 1. The treatment and heterogeneity effects of access to agricultural loans on the net farm income of cassava processors.

Sub-sample	Decision stage		Treatment effect
	Have loan access	lack loan access	
Farmers that have access to loan	$E(Y_{1i}\|D_i = 1)= X\delta_{1i} - \sigma_{1ie}\lambda_o$	$E(Y_{0i}\|D_i = 1)= X\delta_{1i} - \sigma_{0ie}\lambda_1$	ATT= $X(\delta_{1i} - \delta_{0i}) + \lambda_1(\sigma_{1ie} - \sigma_{0ie}$
Farmers that did not have access to loan	$E(Y_{1i}\|D_i = 0)= X\delta_{0i} - \sigma_{1ie}\lambda_0$	$E(Y_{0i}\|D_i = 0)= X\delta_{0i} - \sigma_{0ie}\lambda_0$	ATU= $X(\delta_{1i}- \delta_{0i}) + (\sigma_{0ie} - \sigma_{1ie})\lambda_0$
Heterogeneity effect (HH)	$HH_{1i}= \delta_{1i}(X_{1i}- X_{0i}) + \sigma_{1ie}(\lambda_1 - \lambda_0)$	$HH_{0i}= \delta_{0i}(X_{1i}- X_{0i}) + \sigma_{0ie}(\lambda_1 - \lambda_0)$	TH=HH_{1i} -HH_{0i}

N.B. – ATT means the average treatment on the treated, ATU = the average treatment on the untreated, TH = transitional heterogeneity, $\sigma_{1ie}$and σ_{0ie} are the covariance of the error terms and λ= the inverse Mills' ratios.

Table 2. The definition, description and a *priori* expectations for the variables used in the model.

Variable	Description of variable	Type of data/Unit of measurement	A *priori* expectation
Dependent variable			
NFI	Net farm income from cassava processing	Covariate/naira	+
LOANACES	Access to agricultural loan	Dummy; 1=loan access, 0=no loan access	+
Explanatory variables			
AGE	Age of the cassava processor	Covariate/years	+/-
GENDER	Gender of cassava processor	Dummy:1=male, 0=female	+/-
EDU	Years spent in acquiring formal education	Covariate/years	+
FAMSZ	Number of family members in each cassava processor's household	Covariate/count	+
OCCUP	Primary occupation of the cassava processor	Dummy:1=cassava processing, 0=other occupation	+/-
WORKHH	Number of working members of the household	Covariate/count	-
EXP	Number of years spent in cassava processing	Covariate/count	+
ENT_SIZE	Processing capacity per week	Covariate/kilogramme	
OFFINC	Access to off-farm income	Dummy:1=access , 0=otherwise	-/+
MARSTAT	Marital status of cassava processor	Categorical:1=single, 2=married, 3=separated/divorced,4=widowed /widower	+
LOANPOLICY	Awareness about government credit policy	Dummy:1=access , 0=otherwise	+
EXT_VISIT	Frequency of visits by extension agents annually	categorical:4.=Very Frequent, 3=Less frequent, 2=sometimes, 1=rarely 0=never	
ASS_MEM	Trade association membership (cooperative/farmer groups)	Dummy: 1=belong, 0=not belong	+

Budgetary analysis

Budgetary analysis was employed to determine the profitability of the cassava processing enterprise in Oyo State. Profitability ratios including gross margin, benefit cost, operating expense and return on investment ratios were computed.

Gross margin = $P_iQ_i - rC_i$ (7)

Net income/profit (π_i) = $P_iQ_i - (rC_i + K_i)$ (8)

where Pi = price per unit of cassava produce sold (naira), Qi = quantity of cassava produce sold (kg). The variable costs include expenditures on labor, processing equipment, purchase of raw cassava, and transportation. K_i is the cost of i^{th} fixed inputs, including rent, firm tax, and depreciation on cassava processing equipment.

Results and Discussion

Socio-economic characteristics of cassava processors

Table 3 presents socio-economic characteristics of cassava processors. The results in Table 2 show that respondents had a mean age of 41.1±7.5 years, indicating that respondents were active physically and belonged to the economic age category. These processors were female (0.72±0.45) on average. This shows that the female gender dominates the small-scale cassava processing industry in Oyo State, which may constrain loan access among the processors. This is because, in agrarian societies like Nigeria, traditional values and customs, which tend to promote gender inequality, are still prevalent. Thus, the female gender is at a disadvantage point in asset acquisition and possession. This view is supported by Oluwasola (2009) and Eze and Nwigbo (2014). On average, cassava processors did not have access to agricultural loans (0.23±0.42) and did not belong to trade associations (0.42±0.23). Of the few that had loan access, informal loan sources, preferably rotatory contribution and highly volatile, agricultural non-friendly microfinancing options dominate their loan profile. With this, it becomes clear that the formal agricultural loan is not a common practice among cassava farmers. In agreement with Adegbite (2009) and Adeyonu et al. (2017), the low patronage of the agricultural loan may be due to poor awareness and stringent loan requirements. With the increasing capital commitments, motivation through farmers' group financing and other supportive efforts to transform the industry under the agricultural promotion policy, there is still a great deal of work to be done for the cassava processing sub-sector to gain significantly from the renewed credit policies in Nigeria.

Table 3 also revealed that the respondents were averagely married (1.96±0.50). This submission follows an assertion by Eze and Nwigbo (2014) that cassava processors have a large responsibility size and are willing to use loans. The mean years spent in acquiring education were 8.05±5.89. This is an indication that most of the respondents were learned and, as such, should be articulate in making loan decisions. This view agrees with Ibrahim and Bauer (2013) that educated households adapt to new agricultural methods, cope with risks and increase loan access more readily than their less-educated counterparts. Processors had a mean household size of 5.04±2.48 members per household. It suggests that cassava processors could gain from the moderate availability of cheap family labor. The average number of years spent processing cassava was 8.05±5.89 years, meaning that respondents had been involved in this practice for a considerable number of years.

Moreover, Table 3 revealed that, on average, cassava processing was the primary source of income (1.47±0.50) for the households with an average monthly income of ₦47,216.67±₦19,200.05 (US$131.16±US$53.33). The wide variation in household income may be relevant to loan behaviour among cassava processors. On average, cassava processors were ignorant of government loan policies (0.27±0.47). Going by this, it becomes obvious that cassava processors are poorly informed about government loan policies. As such, measures should be put in place to enlighten processors on farmers' friendly loan policies that can significantly improve farm comparative advantage and performance. This submission complies with the findings of Kuye (2015), who advocated for the development and implementation of cassava friendly loan packages in Nigeria.

Table 3. Socio-economic characteristics of cassava processors in Oyo State.

Socio-economic characteristics	Mean	Standard deviation
Age (years)	41.15	7.46
Gender	0.72	0.45
Loan access	0.23	0.42
Loan source	0.75	1.57
Membership of trade associations	0.42	0.231
Marital status	1.96	0.50
Education qualification	8.05	5.89
Household size	5.04	2.48
Years of experience	8.37	5.89
Occupation type	1.47	0.50
Monthly income (naira)	47,216.67	19,200.05
Knowledge of Government loan policies	0.27	0.47

Profitability of small-scale cassava processing in Nigeria

Table 4 shows the profitability of small-scale cassava processing. The results in Table 3 reveal that cassava processors spent ₦113,853.17 ($3.6.26) on average as a total variable cost per production cycle**.** The variable cost component alone accounted for 93.9% of total costs, of which the cost of raw cassava alone constituted about 54.1%. This indicates that for every ₦100.00 (US$0.28) invested in cassava processing, an average sum of ₦93.87(US$0.26) is spent on variable input alone. Total revenue was ₦131,739.65 (US$365.94), and a total sum of ₦121,289.78 (US$336.92) was incurred in a production cycle. On average, processors received a gross margin of ₦17,886.48 (US$49.68) and earned a net income of ₦10,449.87 (US$29.03) per production cycle. On a monthly basis, an average of 4 cycles was made, equivalent to a ₦41,799.48 (US$116.11) net farm income. This earning capacity is far above the current national minimum wage of ₦30,000.00 (US$83.33) of the nation and is an indication that cassava processing could be a useful farm venture for alleviating poverty in Nigeria. Table 3 further reveals that GMR and OER were 0.14 and 0.82, respectively. From this, it is clear that for every ₦100 ($0.28) invested in cassava processing, processors spent about ₦82.0 (US$0.24) on operating input alone. This is an indication that operating expenses in cassava processing are high, as such, expanding cassava processing output may require financial support. Similarly, BCR and ROI were 1.09 and 0.09, which reveals that for every ₦100 ($0.28) investment made in cassava processing, an average gain of ₦9.00 ($0.03) is earned, amounting to 9% returns per production cycle. This return on capital invested is less than the conventional interest rate in Nigeria and could discourage capital commitments to cassava processing among potential investors.

Table 4. Budgetary analysis showing the profitability of small scale cassava processing.

Item	Amount (₦)	% contribution
Total revenue from cassava products (TR)	131,739.65	
Variable costs (VC)		
Cost of harvested/purchased cassava	61,650.01	54.15
Transportation cost (fufu and gari)	2,619.25	2.30
Processing cost (fufu and gari)	47,489.62	41.71
Labor cost	2,094.29	1.84
Total variable costs (TVC)	113,853.17	93.87
Fixed costs (FC)		
Business tax	1,440.36	19.37
Depreciated on gari processing equipment	1,979.60	26.62
Depreciated on fufu processing equipment	4,016.65	54.01
Total fixed costs (TFC)	7,436.61	11.96
Total costs (TC)	121,289.78	
Gross margin (TR – TVC)	17,886.48	
Net income/profit (GM − TFC)	10,449.87	
Profitability ratio		
Gross margin ratio (GMR)	0.14	
Benefit cost ratio (BCR)	1.09	
Operating expense ratio (OER)	0.82	
Returns on investment (ROI)	0.09	

**Statistically significant at 5%; currency conversion rate= US$1.00 = ₦360.00.

Determinants of access to agricultural loans among cassava processors

Table 5 presents the determinants and marginal effects of access to agricultural loans on the net farm income of small-scale cassava processors. The ESR model has a significant Wald-test, chi-square likelihood ratio (LR) test (5.59, -69.856, *p*=0.018), depicting that the model is a better fit than the exogenous model at predicting loan access. The Wald-test depicted that predictor variables significantly contributed to changes in the outcome variable. Moreover, the significance of $?_1$ implies that the sample was affected by selection bias, and the regression estimate would be spurious if the OLS regression model was used. Since $?_1$ was positive (*p*<0.01), processors that had access to agricultural loans had a higher net farm income than those that did not have loan access. The positive $?_0$ confirmed that there was a clear difference between the net farm income of the cassava processors that had access and lacked access to agricultural loans in Oyo State.

The first column in Table 5 presents the probit result of the ESRM selection model for the socio-economic factors affecting access to agricultural loans. In conformity with the *a priori* expectations, coefficients of farmers' education (β=0.072, *p*<0.01), marital status (β=0.706, *p*<0.1) and enterprise size (β=0.002, *p*<0.05) had a positive correlation to agricultural loan access while the coefficients of access to off-farm income (β=-0.164, *p*<0.01) and membership of trade associations (β=-1.686, *p*<0.01) were negatively signed. By implication, cassava processors that were married, highly educated, socially inclusive, earned meager off-farm income and had a large processing unit were more likely to access agricultural loans in the study area. This finding agreed with the submissions by Ibrahim and Bauer (2013) and Omodara et al. (2021) but contradicted Eze and Nwibo (2014) and Kiplimo et al. (2015).

The significant positive relationship between the number of years cassava processors spent in formal education and agricultural loan access indicates that cassava processors with high education status are at a vantage point when approaching agricultural loan sources. As shown in Table 5, a unit increase in processors' years of education will likely increase the possibility that cassava processors will access the loan by 7.6%. As indicated earlier, the mean number of years each cassava processor spent acquiring formal education was 8 years. This suggests that the highly educated cassava processors are more likely to access loans much faster than the poorly educated ones, probably because literate processors understand the procedures necessary for loan access at thrifts and microfinance banks that are dominant sources of agricultural loan facilities in the study area. This finding conformed with Ibrahim and Bauer (2013) but contradicted the submission by Eze and Nwibo (2014). In the same vein, a unit increase in the enterprise size will increase the likelihood of accessing agricultural loans by 0.2%.

This is because farms with large processing capacity, all things being equal, have needs for more loans to meet the operational requirement, as emphasized by Oluwasola (2009). Such firms may leverage on farm physical assets as collateral to secure loans. Increasing agricultural loan access is, therefore, germane to expanding the cassava processing industry in Oyo State.

On the other hand, off-farm income is a proxy for household wealth, a unit increase in the off-farm income of cassava processors would decrease the possibility of accessing agricultural loan facilities by 16.4%. Thus, low income earning processors have a higher tendency to access agricultural loans than their high income earning counterparts. This suggests that as the income from other sources rises, the likelihood that a cassava processor will access agricultural loans declines rapidly, indicating that, in smallholder agribusiness, off-farm income tends to serve as working capital and provides an incentive for cassava processors to expand their business portfolio. This is because income from other sources can serve as processors' equity capital and become handy for meeting financial obligations arising from the enterprise operation, thereby discouraging the need for the loan. This submission disagreed with Kiplimo et al. (2015) that high income earning processors are more likely to have access to agricultural loans than their low-income counterparts.

In the same vein, a unit increase in the marital status of processors from the single to the married would increase the possibility of accessing agricultural loan facilities by 70.6%. This suggests that when the responsibilities of processors increase, the drive for loan acquisition will rise correspondingly. It should be recalled that the majority of the processors had a medium household size and invariably had access to cheap labor. So, there was likelihood that net household labor contribution to cassava processing was positive which should be a possible drive for loan acquisition. The finding disagreed with the findings of Ololade and Olagunju (2013).

Trade association membership was a proxy for social capital and had a positive and significant correlation with access to agricultural loans. According to Table 5, there were high tendencies that processors that were members of one or more trade associations would have access to agricultural loans. It is reasonable to say that, during the loan process, processors that belong to farmers' groups may probably leverage their membership status as collateral for loan acquisition. Further, traders' group membership may improve information awareness, lower loan transaction costs and other loan barriers to loan access. Thus, trade association membership can be an effective tool against poor agricultural loans in Nigeria. There is a continuous effort to develop farmers' capital base through a farmer group system. This finding, therefore, does not only embrace group loan system, but further admits that socio-inclusiveness is an important factor in overcoming the problem of persistent poor credit access among small-scale cassava processors.

This study thus agrees with the findings of Omodara et al. (2021) that association membership limits credit constraints among Nigerian farmers.

The marginal effect of access to agricultural loans on the net farm income of small-scale cassava processors

The second stage of ESRM in Table 5 captures the factors determining the net farm income of small-scale cassava processors that had loan access and those that did not have loan access, as presented in columns 4 to 7 of Table 5. This result reveals that the net farm income of cassava processors that had access to agricultural loans was influenced mainly by education (β=0.019; $p<0.1$), number of family members working (β=0.241 $p<0.01$), processors' experience (β=0.028, $p<0.05$) and enterprise size (β=0.001, $p<0.01$). On the other hand, the processor's age (β=-0.017, $p<0.01$), the number of working family members (β=0.060, $p<0.05$) and the processors' experience (β=0.005, $p<0.01$) influenced the net farm income of cassava processors that lacked access to agricultural credits.

According to Table 5, the insignificance of age, gender, family size, and occupation of cassava processors that accessed agricultural credit implies that the role of these variables is negligible to improving the net-farm income of processors that had access to agricultural loans. Also, the insignificance of years of education and enterprise size in the net farm income equation for processors that lacked access to agricultural loans and the significance of these two variables in the net farm income equation for the processors that had access to agricultural loans is an indication that, in credit constraint conditions, cassava processors with a higher level of education increase their net farm income significantly and agricultural loans can help cassava processors that have small processing farms to equal the net farm income of those that have large processing farms. Table 5 further reveals that if processors that have agricultural loan access have an additional working household member, their net farm income will increase by about 24%, whereas it will decline by 6% if cassava processors have no access to agricultural loans. This reflects the fact that processors whose family members earn income may probably have access to family loans for cassava processing operations. Similarly, an additional year of experience in cassava processing increases the net farm income of processors that had loan access by about 3%, whereas it increases the net-farm income by 0.5% among processors that lacked access to agricultural loans. Furthermore, the coefficient of the processor's age had a negative correlation with the net farm income of only the processors that lacked loan access. So, if the age of processors that lacked loan access increases by 1%, their net farm income will decline by 1.7%. This suggests that loan access impacts more negatively on the net farm income of prime-aged than young borrowers that lack access to loans, probably due to farm management practice differentials. This study, therefore, disagreed with the findings of Lin et al. (2019) that credit constraint affects the income of young farmers more readily than the old processors. It should be noted that the average sample age of cassava processors is 41 years, meaning there were a handful of prime-aged individuals among the processors. Unless pragmatic decisions are made to address this issue, poor access to agricultural loans will continue to hamper agribusiness growth in the study area.

Table 5. Full information likelihood estimates for determinants of agricultural loan access and its effects on the net-farm income of small-scale cassava processors in Oyo State.

Variable	Access to agric. loan		Net farm income of cassava processors			
			Loan access		No loan access	
	Coef.	Std.err.	Coef.	Std.err.	Coef.	Std.err.
AGE	-0.042	0.028	0.005	0.009	-0.017***	0.006
GENDER	-0.235	0.344	0.135	0.133	-0.055	0.076
EDU	0.072***	0.028	-0.019*	0.011	0.000	0.007
FAMSZ	0.008	0.074	-0.014	0.028	0.012	0.018
OCCUP	1.875	1.999	0.224	0.144	-0.015	0.071
WORKHH	0.088	0.143	0.241***	0.069	-0.060**	0.027
EXP	0.022	0.032	0.028**	0.013	0.005***	0.008
ENTSIZE	0.002**	0.001	0.001***	0.000	-0.001	0.000
OFF_INCOME	-0.164***	0.061				
MARSTRT	0.706*	0.390				
LOANPOLICY	-0.028	0.341				
EXT. VISIT	-1.067	1.918				
ASS. MEM	-1.686***	0.649				
CONSTANT	8.251	3.821	11.401***	0.619	9.494***	0.301
/lns1	1.158***	0.338				
/lns2	1.141***	0.088				
ρ_0	1.156***	0.376				
ρ_1	-0.743***	0.274				
sigma_1	-0.314	0.106				
sigma_2	-0.319	0.028				
rho_1	0.820	0.254				
rho_2	0.631	0.165				
LR test of indep. eqns.: chi2(1) = 5.59, Prob > chi2 = 0.0181						

N.B. – Log likelihood ratio = -69.856, ***significant = 1%, ** significant = 5%, and *significant = 10%.

Income effects of access to agricultural loans in cassava processing

Table 6 presents the result of the difference in the annual net-farm income of cassava processors due to access to agricultural loans. The income treatment effect value (ATT) of processors accessing agricultural loans is ₦79,350.68 ($220.42);

the income treatment effect (ATU) for those that did not access agricultural loans is ₦33,967.68 ($94.35). If the processors that accessed agricultural loans had not done so, their income treatment effect would have been ₦55,140.39 ($153.17); if processors that did not access loans had accessed agricultural loans, their income treatment effect would have been ₦55,325.41 ($153.68). Hence, the average treatment effect (ATT) on the income of processors that accessed loans was ₦24,140.29 ($67.06). In other words, cassava processors that had access to agricultural loans earned additional ₦24,140.29 ($67.06) monthly, mainly due to loan access. Similarly, cassava processors that did not have access to agricultural loans would earn additional ₦21,357.73 ($59.33) if access to agricultural loans was secured. The transitional heterogeneity effect was ₦2,852.56 ($7.92). This implies that only about ₦2,852.56 ($7.92) of the total income effects discussed above was attributed to other interventions aside agricultural loan access.

Table 6. Heteroskedasticity effects of agricultural loan access on the net farm income of small-scale cassava processors.

Outcome	Loan access status	Predictions		Treatment effect (naira)
		Loan access	No loan access	
Net farm income (naira)	Processors with agricultural loan access	79,350.68	55,140.39	24,140.29***
	Processors without agricultural loan access	55,325.41	33,967.68	21,357.73***
	Heterogeneity effect	24,025.27	21,172.71	2,852.56***

N.B.*** means significant at $p<0.01$.

Further, the results from Table 6 show positive and significant effects of access to agricultural loans on the net farm income. In intervention studies, relying solely on the predicted difference in income effects between cassava processors that had access to agricultural loans and those that did not have access to loans may be misleading because there is no provision for the control of differences in the group attributes (Omodara et al., 2021; Ojo et al., 2020). Therefore, though it accounts for endogeneity resulting from the inability to account for missing data (counterfactual scenario), parameter estimates from the endogenous switching regression model may not be sufficient, even if not misleading. Thus, direct coefficients from the model may not be appropriate as the ATT. To estimate the causal effects of access to agricultural loans on the net farm income of cassava processors, average treatment effect (ATE) and average treatment on the treated (ATT) were estimated by complementing endogenous treatment with augmented inverse-probability-weighted regression adjustment (AIPWRA) as a robustness check. Hence, the estimates from the endogenous switching regression model were discussed. Endogenous switching regression was first fitted with endogenous treatment effects, and ATE and ATT were then estimated. As indicated in Table 7, the estimated average treatment effect (ATE) of access to agricultural loans on the net farm income of average cassava processors was about 4.5%, positive and statistically significant (p<0.01). This estimate predicts that an average cassava processor's net farm income in the study area would be impaired with about 4.5% of the net farm income if he/she lacked access to agricultural loans. Similarly, the conditional treatment effects which measure the ATT of access to agricultural loans on the net farm income of the treated group are about 35% (p<0.01). It suggests that cassava processors that had access to agricultural loans in the study area would improve the net farm income by about 35% more than it would be if he/she had no access to agricultural loans. This submission agreed with Omodara et al. (2021) and Abdallah et al. (2018), who reported that removing credit constraints could result in more than 24% improvement in farmers' net worth.

The *ex-post* estimates of the causal effects of access to agricultural loans on the net farm income of cassava processors from the AIPWRA model are presented in Table 7. The result from the augmented inverse probability weighted regression adjustment estimation indicates that lack of access to agricultural loans impaired the net farm income of cassava processors in the study area. From Table 7, the ATT and POM were approximately 4.9% and 37%, respectively, meaning that the average treatment effect of agricultural loan access on the net farm income of processors that had loan access was positive and significant (p<0.001). Similarly, access to agricultural loans boosted the net farm income from cassava processing and translated to spill-over effects on the welfare of cassava processors in the study area. The positive impact of access to agricultural loans on the net farm income of cassava processors is consistent with the studies of Omodara et al. (2021), Ojo and Baiyegunhi (2020), Ojo et al. (2019) in Nigeria, whose findings have agreed that credit constraints have a negative impact on farmers' welfare and income.

Table 7. Robustness check tests for income treatment effects of access to agricultural loans in cassava processing (Endogenous switching regression model and inverse-probability-weighted regression adjustment).

Model	Endogenous switching regression		Augmented inverse-probability-weighted regression adjustment	
Treatment effects	Average treatment effect (ATE)	Average treatment on the treated (ATT)	Average treatment on the treated (ATT)	Potential-outcome mean (POM)
Coefficient	0.045***	0.351***	0.049***	0.371***
Std. err.	0.012	0.199	0.0050	0.082

Note: data used 500 replications to bootstrap the standard errors after changing bootstrap replications between 100 and 1,000 with no significant changes.

*** means significant at p<0.01.

A post-estimation analysis of ATE and ATT was carried out after fitting the Stata command *movestay* for endogenous switching regression. The TT is the conditional treatment effect, while ATE estimated after *movestay* is the potential outcome.

Constraints facing the cassava processing industry in accessing agricultural loans

Ranked in decreasing order of importance, Table 8 shows that respondents agreed that business risks (3.96±1.04; RSI=0.79), enterprise size (mean=3.75±0.80; RSI=0.75), and high interest rate (mean=3.18±1.56; RSI=0.64) mainly constrained effective access to agricultural loans in cassava processing, while high collateral requirement (Mean=2.36±1.06, RSI=0.47) was disregarded as a constraint to loan access in cassava processing. There is a general perception that business risks and interest rates pose great threats to the ability of cassava processors to access loan facilities despite the various agribusiness financing strategies implemented in the cassava value chain. This study is supported by the findings of Ayegba and Ikani (2013).

Table 8. Constraints facing cassava processors in accessing agricultural loans.

Constraint	WMS	Std. dev.	RSI	Rank
Business risks	3.96	1.036	0.79	1st
Enterprise size	3.75	0.799	0.75	2nd
High interest rate	3.18	1.565	0.64	3rd
High collateral requirement	2.36	1.062	0.47	4th

Conclusion

This study presents findings on how socio-economic attributes of cassava processors determine access to agricultural loans and evaluates the implications of agricultural loan access on the net farm income from cassava processing. The results showed that access to loan facilities was limited among cassava processors mainly due to poor education and membership of trade associations; small processing capacity, and low earnings from off-farm sources. Cassava processors had limited access to agricultural loans. Funds are sourced mainly from informal and non-farm friendly loan issuers. However, cassava processing remains a profitable venture in Oyo State. The study deduced that the net farm income of processors that had access to agricultural loans was affected by education, number of working household members, processing experience, and enterprise size while only age of processors, number of working household members and processing experience influenced the net farm income of those that lacked access to agricultural loans. However, the roles of age, gender, family size and occupation of the processors were negligible in determining the net farm income of processors that had access to agricultural loans. More so, access to agricultural loans positively impacted farm income from cassava processing and had a spillover welfare effect in the cassava processing industry. Given favorable loan access conditions, the cassava processing industry in Nigeria is poised to gain tremendously from agricultural loans through the expansion of processing scale, cassava output, farm income, and good returns on investment. It was, however, gathered that business risks, enterprise size, and interest rate militate against the realization of improved access to agricultural loans among cassava processors in Nigeria. On this note, certain recommendations were made.

1. It is necessary to activate farm support service for cassava processors in Oyo State. Cassava processors should be given high priority in the ongoing agricultural loan programs in Nigeria to ease loan access and technical constraints limiting the capacity of the industry.
2. Government credit interventions in the cassava processing sub-sector should target young processors. This is because, processors' age was paramount to loan access and young processors had the edge in credit use in the study area.
3. The membership of trade networks has become a key factor in accessing loans. Findings from this study have shown that majority of the processors do not belong to a trade association, therefore, enlightenment programs about the benefits of inclusive social membership are necessary to help cassava processors gain social collateral and capital that will enhance chances of benefiting optimally from the renewed farmers' friendly agricultural loan facilities in Nigeria.
4. The fact that the net farm income of cassava processors with lower education and a large processing capacity is more likely to be affected by access to loans provides a basis for more training on the use of agricultural loans for cassava processors. Furthermore, lenders and policymakers must protect the interests of the less educated cassava processors in formulating loan policies in Nigeria.

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VEZA IZMEĐU PRISTUPA POLJOPRIVREDNIM KREDITIMA I PRIHODA GAZDINSTAVA MALIH PRERAĐIVAČA MANIOKE U DRŽAVI OJO, NIGERIJA: REGRESIONI MODEL IZMENE ENDOGENE PROMENLJIVE

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R e z i m e

Poljoprivredni kredit je suštinsko sredstvo za transformaciju komercijalne poljoprivrede u profitabilni poslovni poduhvat. Imajući to u vidu, ovim istraživanjem su ispitivane determinante pristupa poljoprivrednim kreditima i profitabilnosti prerade manioke u malom obimu. Takođe je testirano da li je pristup poljoprivrednim zajmovima uticao na dobit gazdinstava prerađivača manioke u državi Ojo uz pomoć analitičkih kalkulacija, regresionim modelom izmene endogene promenljive (engl. *endogenous switching regression model* – ESRM) i prilagođavanjem regresije proširenim ponderisanjem inverznom verovatnoćom (engl. *augmented inverse probability weighted regression adjustment* – AIPWRA) za proveru robusnosti modela. Za prikupljanje informacija od 120 prerađivača manioke korišćena je tehnika višeetapnog slučajnog uzorkovanja. Rezultati su otkrili da se preradom manioke pretežno bave žene, i da je prosečna starost prerađivača 41,1±7,5 godina. Samo 23% ispitanika je imalo pristup poljoprivrednim zajmovima, koji su prvenstveno dobijani neformalno. Analitičkom kalkulacijom je utvrđeno da su prerađivači ostvarili prosečnu dobit gazdinstva od 10.449,87₦ (29,03 USD) u proizvodnom ciklusu. Regresiona analiza izmene endogene promenljive pokazala je da je verovatnije da obrazovani prerađivači manioke i oni u braku koji su bili društveno uključeni i koji su imali veliku jedinicu za preradu i zarađivali oskudne prihode van gazdinstva pristupe poljoprivrednim zajmovima. Pored toga, obrazovanje (β=0,019, $p<0,1$), broj članova porodice koji rade (β=0,241, $p<0,01$), iskustvo prerađivača (β=0,028, $p<0,05$) i veličina prerađivačke jedinice (β=0,001, $p<0,01$) uticali su na dobit gazdinstava prerađivača koji su imali pristup poljoprivrednim zajmovima. Efekat tretmana iz rezultata AIPWRA otkrio je da su ATT i POM za prerađivanje manioke bili 4,5% odnosno 37%. Poslovni rizici, mala veličina prerađivačke jedinice i visoka kamatna stopa bili su glavna ograničenja za pristup poljoprivrednim zajmovima. Iz navedenog sledi da je potreba za sistemom tehničke podrške među prerađivačima manioke neizbežna. Štaviše, prerađivače manioke treba podsticati da se pridruže trgovačkim

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udruženjima, a mladim prerađivačima treba dati prioritet u kreditnim inicijativama za preradu manioke.

Ključne reči: poljoprivredni kredit, kreditna politika, mali poljoprivrednik, prerada manioke, profitabilnost**,** ESRM, AIPWRA.

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Sažetak je kratak informativni prikaz sadržaja članka koji čitaocu omogućava da brzo i tačno odredi njegovu relevantnost. U interesu je autora da sažetak sadrži termine koji se koriste za indeksiranje i pretraživanje. Sažetak ne sme da sadrži reference. Sastavni delovi sažetka su cilj istraživanja, metode, rezultati i zaključak. Sažetak treba da ima od 200 do 250 reči. Reč „Sažetak" piše se boldovano i uvlači jednim tabulatorom, nakon čega slede dve tačke, a zatim tekst sažetka.

Ključne reči
Ključne reči su termini ili fraze koje najbolje opisuju sadržaj članka za potrebe indeksiranja i pretraživanja. Broj ključnih reči može biti od 3 do 10. Navode se ispod sažetka. Naslov „Ključne reči" piše se boldovano i uvlači jednim

tabulatorom. Nakon toga slede dve tačke, a zatim nabrajanje ključnih reči malim slovima, sa tačkom na kraju. Treba izbegavati korišćenje ključnih reči koje se nalaze u naslovu rada. Ključne reči se dostavljaju na srpskom i engleskom jeziku posle sažetaka na oba jezika.

Uvod

Uvod treba da sadrži informacije o dosadašnjim istraživanjima po navedenom pitanju i šta se datim istraživanjem želi postići. Prilikom osvrta na literaturu, navesti autora i godinu, a autora citirati u spisku literature. Naslov „Uvod" piše se sa prvim velikim slovom, centrirano i boldovano, nakon čega sa jednim razmakom ispod naslova sledi tekst uvoda poravnat po levoj i desnoj margini. Svaki novi pasus uvlači se jednim tabulatorom. Ova pravila važe i za sva ostala poglavlja.

Materijal i metode

Materijal i metode treba izložiti jasno uz objašnjenje svih primenjenih postupaka u radu. Opšte poznate metode izložiti kratko, a detaljnije ih objasniti ukoliko se odstupa od ranije objavljenih postupaka. Za radove eksperimentalnog karaktera obavezno navesti način statističke obrade podataka. U ovom poglavlju, kao i u poglavlju „Rezultati i diskusija", po potrebi se mogu dati i određena podpoglavlja.

Rezultati i diskusija

U poglavlju „Rezultati i diskusija" interpretiraju se podaci dobijeni na osnovu zapažanja i izvršenih eksperimenata. U komentaru rezultata treba se pozivati na literaturu koja se navodi na kraju rada, čime se obezbeđuje poređenje dobijenih rezultata sa dosadašnjim saznanjima u toj oblasti.

Zaključak

U zaključku treba ukratko navesti najznačajnije rezultate dobijene u radu. Izbegavati nabrajanje svih rezultata istraživanja sa ponavljanjem brojčanih vrednosti koje su prethodno već navedene u poglavlju „Rezultati i diskusija". Zaključak ne sme da sadrži reference.

Zahvalnica

Zahvalnica treba da sadrži naziv i broj projekta, odnosno naziv programa u okviru koga je rad nastao, kao i naziv institucije koja je finansirala projekat ili program.

Literatura

Poglavlje „Literatura" treba da sadrži samo radove citirane u glavnom tekstu. Rad citiran u tekstu treba da sadrži prezime autora i godinu. Ako citat obuhvata jednog autora on se navodi kao Jalikop (2010) ili (Jalikop, 2010). Kada citat obuhvata dva autora on se navodi kao Sadras i Soar (2009) ili (Sadras i Soar, 2009). Ako se u tekstu citiraju više od dva autora posle prezimena prvog autora navodi se skraćenica „et al.", a zatim godina. Ovakav citat navodi se kao Lehrer et al. (2008) ili (Lehrer et al., 2008). Ako se za određeni problem istovremeno citira više radova onda se oni hronološki nabrajaju. Odvajanje većeg broja citiranih radova van

zagrade vrši se zarezom (,) a u zagradi tačkom i zarezom (;). Ako se citiraju dva ili više rada istog autora oni moraju biti poređani prema hronološkom redu (1997, 2002, 2006, itd.). Ukoliko se određeni autor pojavljuje nekoliko puta u istoj godini, dodaju se slova (2005a, b, c, itd.). Citate ličnih komunikacija i neobjavljenih podataka treba izbegavati, osim ako je to apsolutno neophodno. Takvi citati bi trebali da se pojave samo u tekstu (npr. Brown, lična komunikacija), ali ne i u spisku referenci.
Literatura koja je citirana u tekstu navodi se u spisku referenci u originalnom obliku, po abecednom redu, bez numeracije. Ako se citira veći broj radova istog autora najpre se navode radovi kada je autor sam, a zatim kada su prisutna dva i više autora. Ako se u nekoj od ovih kategorija javlja veći broj radova, treba ih hronološki srediti po godinama (1997, 2002, 2006, itd.), a ako se u istoj godini javlja veći broj radova dodaju se slova (2005a, 2005b, 2005c, itd.). Literaturni podatak treba da sadrži: prezime autora, početno slovo imena, godinu izdanja u zagradi, naslov rada, naziv časopisa, volumen i broj stranica (prva-poslednja). Prilikom citiranja knjiga navodi se izdavač i mesto izdavanja. Redovi svake reference posle prvog reda moraju biti uvučeni. U časopisu se koristi APA - Publication Manual of the American Psychological Association citatni stil.

Primeri navođenja referenci su sledeći:

Periodičan časopis
Gvozdenović, S., Saftić Panković, D., Jocić, S., & Radić, V. (2009). Correlation between heterosis and genetic distance based on SSR markers in sunflower (Helianthus annuus L.). *Journal of Agricultural Sciences*, *54*, 1-10.

Knjiga
Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedures of statistics*. New York: McGraw-Hill Book Company.

Poglavlje u knjizi
Bell, R.L., Quamme, H.A., Layne, R.E.C., & Skirvin, R.M. (1996). Pears. In J. Janick & J.N. Moore (Eds.), *Fruit breeding, Volume I: Tree and tropical fruits.* (pp. 441-514). New York: John Wiley and Sons, Inc.

Zbornik
Behera, T.K., Staub, J.E., Behera, S., Rao, A.R., & Mason, S. (2008). One cycle of phenotypic selection combined with marker assisted selection for improving yield and quality in cucumber. In M. Pitrat (Ed.), *Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae* (pp. 115-121). Avignon.

Teza
Singh, N.K. (1985). *The structure and genetic control of endosperm proteins in wheat and rye*. University of Adelaide.

Izveštaj
Ballard, J. (1998). *Some significant apple breeding stations around the world*. Selah, Washington.

Veb sajt
Platnick, N.I. (2010). The world spider catalog, version 10.5. *American Museum of Natural History*. Retrieved February 12, 2016, from http://research.amnh.org/entomology/spiders/catalog/index.html

Rezime
Rezime na srpskom jeziku (za radove napisane na engleskom jeziku) ili na engleskom jeziku (za radove napisane na srpskom jeziku) navodi se na kraju rada i treba da ima od 200 do 250 reči. Ispred osnovnog teksta rezimea, navodi se naslov rada, puno ime, srednje slovo i prezime svih autora i naziv i adresa ustanove autora. Naslov „Rezime" piše se razmaknuto i centrirano. Nakon naslova sledi jedan razmak, a zatim tekst rezimea, uvučen jednim tabulatorom. Neposredno nakon teksta rezimea, navode se ključne reči, sa tačkom na kraju. E-mail adresa autora za kontakt navodi se ispod crte, pri dnu stranice.

Tabele
Tabele obeležene arapskim brojevima (1, 2, itd.) praćene naslovom treba da se nalaze na odgovarajućem mestu u tekstu, u fontu 9. Maksimalna širina tabela treba da bude 13 cm. One treba da budu jasne, što jednostavnije i pregledne. Treba izbegavati vertikalne crte, a broj kolona ograničiti tako da tabela ne bi bila preširoka. Takođe, treba izbegavati nepotrebnu upotrebu horizontalnih crta. Naslov tabele, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom iznad tabele. Ispod tabele treba dati detaljno objašnjenje skraćenica, simbola i znakova korišćenih u samoj tabeli. Svaka tabela mora biti pomenuta u tekstu.

Ilustracije
Svi grafikoni, dijagrami i fotografije treba da se nazovu „Slika" (1, 2, itd.). Prilažu se na odgovarajućem mestu u tekstu. Grafikone i dijagrame treba uraditi fontom 9, u crno-beloj tehnici i sa maksimalnom širinom od 13 cm. Voditi računa da oni budu čitki i jasni i nakon redukcije veličine. Za svaki grafikon i dijagram treba obezbediti detaljnu legendu bez skraćenica. Fotografije moraju biti visokog kvaliteta da bi se tehnički mogle dobro reprodukovati. Prilažu se u „TIF" ili „JPG" formatu, u crno-beloj tehnici. Naslov ilustracije, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom ispod ilustracije. Svaka ilustracija mora biti pomenuta u tekstu.

Skraćenice i jedinice
U radu treba koristiti samo standardne skraćenice. Merne jedinice treba izražavati u internacionalnom sistemu jedinica (SI). Kod navođenja jedinica posle broja treba da stoji razmak (osim za % i °C). Skraćenice se mogu koristiti i za druge izraze pod

uslovom da se ti izrazi navedu u punom obliku prilikom prvog pominjanja, sa skraćenim oblikom u zagradi. Vrednosti od 1 do 9 mogu se izražavati slovima, a ostali brojevi isključivo numerički.

Nomenklatura

Celokupna nomenklatura (hemijska i biohemijska, taksonomska, genetička itd.) mora biti usklađena sa međunarodnim kodeksima i komisijama, kao što su *International Union of Pure and Applied Chemistry, IUPAC-IUB Combined Commission on Biochemical Nomenclature, Enzyme Nomenclature, International Code of Botanical Nomenclature, International Code of Nomenclature of Bacteria* itd.

Formule

Sve formule i jednačine u radu moraju biti urađene pomoću programa „Word Equation“. Pri pisanju formula, radi preglednosti, ostaviti dovoljno praznog prostora oko same formule. Subskripti i superskripti treba da budu jasni. Prilikom pisanja jednačina treba dati smisao svih simbola odmah posle jednačine u kojoj se simbol prvi put koristi. Jednačine treba da budu numerisane arapskim brojevima, serijski u zagradama, na desnoj strani linije. Svaka jednačina mora biti pomenuta u tekstu kao Eq. (1), Eq. (2), itd.

Nakon objavljivanja rada, autoru za kontakt će biti poslat jedan primerak časopisa.
Mole se svi budući saradnici da rad pripreme prema datom uputstvu, kako bi olakšali rad redakcije časopisa. Ukoliko se rad ne pripremi po navedenom uputstvu neće biti prihvaćen za objavljivanje.

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