Hrvatsko Agro Ekonomsko Društvo

DAES
Društvo agrarnih ekonomistov Slovenije

The Role of Agricultural Economic Research in Sustainable Transformation of Agrifood Systems in Central and South-East Europe

Proceedings

HAED – DAES 2025
International Scientific Conference

Josip Juraj Strossmayer University of Osijek
Faculty of Agrobiotechnical Sciences Osijek

BF | UNIVERSITY OF LJUBLJANA
Biotechnical Faculty

Hrvatsko Agro Ekonomsko Društvo

Croatian Association of Agricultural Economists

DAES
Društvo agrarnih ekonomistov Slovenije

Slovenian Association of Agricultural Economists

Proceedings

HAED – DAES 2025

International Scientific Conference

The Role of Agricultural Economic Research
in Sustainable Transformation of Agrifood Systems
in Central and South-East Europe

18-19 September 2025
Osijek, Croatia

Proceedings

HAED – DAES 2025 International Scientific Conference

Publisher

Josip Juraj Strossmayer University of Osijek,
Faculty of Agrobiotechnical Sciences Osijek,
Vladimira Preloga 1, 31 000 Osijek, Croatia

Editors in Chief

David Kranjac, Croatia
Luka Juvančič, Slovenia

Design

Ras Lužaić, Croatia

The official language of the Conference is English. All papers are peer-reviewed.

ISBN 978-953-8421-18-1

Web page
https://haeddaes.fazos.hr/

ICA Association for European Life Science Universities

B.EN.A. Balkan Environmental Association

Josip Juraj Strossmayer University of Osijek
Faculty of Agrobiotechnical Sciences Osijek

BF UNIVERSITY OF LJUBLJANA
Biotechnical Faculty

Croatian Association of Agricultural Economists (HAED)

and

Slovenian Association of Agricultural Economists (DAES)

in collaboration with

Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, Croatia
Biotechnical Faculty, University of Ljubljana, Slovenia
Faculty of Agriculture University of Zagreb, Croatia
Association for European Life Science Universities (ICA)
Balkan Environmental Association (B.EN.A)
Agricultural Institute of Slovenia, Slovenia
Wageningen University & Research, Netherlands
Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Germany
Swedish University of Agricultural Economics, Sweden
Ministry of Higher Education, Science and Innovation, Slovenia
Faculty of Management, University of Primorska, Slovenia
Faculty of Agricultural Sciences and Food, Ss. Cyril and Methodius University in Skopje, North Macedonia
Faculty of Agriculture and Life Sciences, University of Maribor, Slovenia
University of Belgrade Faculty of Agriculture, Serbia
University of Novi Sad Faculty of Agriculture, Serbia
University of Banja Luka, Faculty of Agriculture, Bosnia and Herzegovina
Biotechnicon Entrepreneurial Center Ltd., Croatia
Lika Potato Producers Association, Croatia
Joint Research Centre (JRC), European Commission, Belgium

organize

HAED – DAES 2025 International Scientific Conference
The Role of Agricultural Economic Research in Sustainable Transformation
of Agrifood Systems in Central and South-East Europe

Programme Committee

David Kranjac, Croatia | Chair
Luka Juvančič, Slovenia | Co-Chair

Members:

Krunoslav Zmaić, Croatia
Emil Erjavec, Slovenia
Mariana Golumbeanu, Romania
Rasa Pakeltiene, Lithuania
Tihana Sudarić, Croatia
Marija Ravlić, Croatia
Črtomir Rozman, Slovenia
Lari Hadelan, Croatia
Štefan Bojnec, Slovenia
Danilo Đokić, Serbia

Scientific Committee

Sanja Jelić Milković, Croatia | Chair
Marija Cerjak, Croatia | Co-Chair

Members:

Tanja Šumrada, Slovenia
Ilona Rac, Slovenia
Jordan Hristov, Germany
Magdalena Zrakić Sušac, Croatia
Jelena Kristić, Croatia
Branka Šakić Bobić, Croatia
Ružica Lončarić, Croatia
Ana Crnčan, Croatia
Antonis K. Kokkinakis, Greece
Maria Popa, Romania
Bojan Matkoski, Serbia

Contents

Enhancing Eco-Scheme Participation: The Impact of Information Framing in a Randomised Controlled Trial

Živa Alif[1], Ana Novak[1], Carl-Johan Lagerkvist[2] and Tanja Šumrada[1]

[1] Biotechnical faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia (ziva.alif@bf.uni-lj.si)
[2] Department of Economics, Swedish University of Agricultural Economics, Ulls hus, Ulls väg 27, 756 51 Uppsala, Sweden

ABSTRACT

Farmers' participation in a new Eco-Scheme aimed at establishing Skylark plots in Slovenia was examined through two consecutive randomized controlled trials utilizing information-based interventions. The first trial employed gain and loss-framing to highlight environmental outcomes, while the second used positive and negative descriptive norms to frame enrolment behavior. Neither intervention produced a significant overall effect on enrolment rates. However, among larger farms and those with prior participation in agri-environmental schemes, the treatments influenced both the decision to enrol and the extent of land enrolled. These findings suggest that generic information framing, when not targeted, may be insufficient to effectively promote farmer uptake of agri-environmental measures.

INTRODUCTION

The sustainable management of natural resources and the conservation of biodiversity within agricultural ecosystems heavily rely on voluntary agri-environmental schemes (AES), which offer financial incentives to farmers for adopting environmentally beneficial practices (Hasler et al., 2022). These schemes include, for instance, Agri-Environmental-Climate Measures (AECMs) and Eco-Schemes under the European Union's Common Agricultural Policy (CAP) (Pe'er et al., 2022). A key challenge to the effectiveness of these initiatives lies in low enrolment rates, on average below 5%, particularly for more demanding measures, which limit their potential to achieve intended environmental outcomes (Alliance Environment, 2019).

Improved access to information often delivered through information campaigns has been associated with increased farmer participation in AES. However, the effectiveness of such campaigns may vary depending on contextual factors, including behavioural and socio-psychological determinants (Schulze et al., 2024). Beyond merely providing information, such campaigns can serve as platforms for behaviourally informed interventions, which present (novel) information in a way that activates psychological mechanisms to support desired behavioural outcomes within a target population (Michie et al., 2008). Among these interventions, nudges have gained increasing popularity. Nudges aim to influence behaviour by modifying the decision-making environment - such as the presentation of information and choices - without altering economic incentives (Thaler and Sunstein, 2008). They are often simple, low-cost tools that can be incorporated into existing policy frameworks (Ferraro et al., 2017). Despite their promise, the effectiveness of nudges remains uncertain due to potential publication bias in the existing literature, which tends to overreport positive results (Mertens et al., 2022).

To test the effectiveness of nudges based on provisioning and framing of information, we implemented two randomized controlled trials (RCTs) examining farmer enrolment in a new Eco-Scheme promoting the establishment of Skylark plots in Slovenia. The first RCT examined the impact of gain and loss framing, grounded in Prospect Theory (Kahneman and Tversky, 1979), which posits that losses are psychologically more salient than equivalent gains. Two treatment letters emphasized either the environmental gains of enrolment or the losses associated with non-enrolment in terms of biodiversity conservation, while a control letter omitted such framing. Although loss framing has demonstrated consistent effectiveness in consumer behaviour research, its effects in agricultural contexts remains uncertain due to the complexity of farm management decisions and farmers' typically business-oriented decision-making processes (Dessart et al., 2019).

In the second RCT, we investigated the influence of descriptive norm framing. Again leveraging the Ministry's out-reach campaign, we tested whether positive or negative framing of social norms - i.e., portraying enrolment as common or rare among peers - would affect farmer behaviour. Descriptive norms convey what is commonly done by others (e.g., "most farmers in your area have enrolled"), and their effectiveness may depend on whether they are framed positively or negatively (Cialdini et al., 2006; Mollen et al., 2021). While several studies have explored social norm nudges in agricultural settings, their findings vary widely, and no prior study has specifically examined the effect of descriptive norm framing on actual enrolment behaviour (Chabé-Ferret et al., 2023; Klebl et al., 2023).

The RCTs were conducted on a case of an Eco-scheme for establishing Skylark plots (hereafter: Skylark scheme), which was introduced in 2023 for the first time. In the Skylark scheme, farmers are required to provide unsown patches on arable land, where cereals, oilseed rape, clover, crimson clover, or clover grass mixture are cultivated on the rest of the field. Each plot needs to be at least 25 m^2 large and at least 2.5 m wide and should be provided at the density of one plot per half a hectare. Therefore, only about 0.5% of the cropping surface is usually lost per hectare. Additionally, while the use of herbicides and pesticides on the plots is discouraged, it is permitted when there is trouble with weeds. As many eligible crops are sown in autumn in Slovenia, Skylark plots are most likely to be established during this time. However, formal enrolment into the scheme takes place in the following spring when farmers submit their annual CAP subsidy application. The payment of 60€ per ha (30€/patch) is then processed by the payment agency in late summer.

The scheme is implemented in five Slovenian lowland regions where Skylarks feed and nest predominantly on arable land. In total, there is 37,852 ha of eligible arable land. However, since only arable land sown with specific crops can be enrolled, the actual area of eligible land is smaller and varies from year to year due to crop rotation. For example, in 2022, 16,787 ha (45 %) of eligible land was sown with eligible crops. The contract duration for farmers is one year, which means all farmers, regardless of their previous enrolment, must decide annually whether to participate. In this way, enrolment in consecutive years and the location of plots may change based on the crop rotation practices of each farm.

MATERIAL AND METHODS

We conducted the RCTs in two consecutive years, using the same design and procedure. In September 2022 (Experiment 1) and in September 2023 (Experiment 2), the Ministry sent information letters to all eligible farmers to raise farmers' awareness about the Skylark scheme and to invite them to enrol. To ensure fair access to information, we purposefully sent letters with identical information to all farmers, except for a short manipulated message in the middle or at the end of the letter that did not convey any essential information regarding the requirements and implementation of the scheme.

In each RCT, individual farms as experimental units were randomly assigned to three equally sized treatment arms: the control group that did not receive the framed information, and two treatment groups that i) received gain and loss framed messages in Experiment 1 and ii) positively and negatively framed descriptive norms in Experiment 2. The randomization was independent in both years and stratified by the five regions where the Eco-scheme is available.

In Experiment 1, we tested a nudge that framed enrolment into the scheme as a gain or a loss for the Skylark population and nature conservation in Slovenia. Based on the literature review, we hypothesised that the farmers who received the loss-framed message would enrol more frequently than farmers in the other two groups.

In Experiment 2, a nudge based on descriptive norm framing was tested. The Ministry again sent information letters to all eligible farmers, where in addition to the material on the scheme the control group received, farmers in the two treatment groups were also provided with information on enrolment rates in the first year and framed the enrolment levels as high or low (Table 1). Based on previous studies, we expected positive descriptive norms to increase enrolment rates compared to both other groups (Mollen et al., 2021), while negative descriptive norms would have no effect.

Our sample consisted of all farms in Slovenia that were eligible to enrol in the Skylark scheme. In Experiment 1, our sample included 4,586 farmers, of which 1,528 were in the control group, 1,530 in the gain-framed group and 1,528 in the loss-framed group. In Experiment 2, 1,517 farmers received control letters, 1,514 received positively framed letters and 1,517 farmers received negatively framed letters, totalling 4,548 recipients.

Table 1. Framed messages used in information letters (note: the original text in Slovene was not bolded).

2022	**Gain framing:**	**Loss framing:**
	"**By implementing** this scheme on your arable land, the breeding conditions for Skylark **can improve** and, hence, **increase the chance** for its chicks' survival. Therefore, by **implementing** this scheme, you are **contributing to the increase** of the population of this endangered bird species and **to biodiversity conservation** in the Slovenian countryside."	"**By not implementing** this scheme on your arable land, the breeding conditions for Skylark **can deteriorate** and, hence, **decrease the chance** for its chicks' survival. Therefore, by **not implementing** this scheme, you are **contributing to the decline** of the population of this endangered bird species and to a **biodiversity loss** in the Slovenian countryside."
2023	**Positive descriptive norm:**	**Negative descriptive norm:**
	"In 2023, farmers in this area enrolled **as much as** 1,041 ha into the scheme and provided **more than** 2,000 Skylark plots.	"In 2023, farmers in this area enrolled **only** 1,041 ha into the scheme and provided **less than** 2,100 Skylark plots."

Enrolment data for both experiments were obtained from the Ministry. The data included the area each farmer enrolled into the Skylark scheme, enrolment into AECM, enrolment into other Eco-schemes (only available in Experiment 2), total farm area and total area of eligible arable land for Skylark scheme, livestock units/ha, geographical region, gender and age.

To evaluate the effectiveness of the framing treatments, we started by using a three-sample test of proportions to compare percentages of enrolment by treatment. Due to the non-normal distribution of enrolled area, we then used the Kruskal-Wallis non-parametric test to investigate if the median for treated and untreated units is the same in terms of the area enrolled. Next, we used a hurdle regression model, as this model aligns with the two decision-making processes that farmers undertake. To maximise their utility, farmers first decide whether to enrol into the scheme. If they decide to enrol, this influences their utility maximising choice regarding the amount of land to enrol (Feng, 2021). In our hurdle model, we included the main effect of interventions as well as other covariates and interactions between covariates and a treatment group for exploratory purposes. The covariates in the model included gender, age, enrolment in other agri-environmental measures, livestock units/ha, and eligible arable land. The knowledge gained through such exploratory analyses can be used for future message targeting, whereby the alignment of message discourses (e.g. a focus on economic vs nature conservation consequences) with farm characteristics may lead to increased effectiveness of interventions for different types of farms. As we had no prior beliefs about the effect of farm characteristics on enrolment in the second and the third model, all covariates and interactions were included in both parts (enrolment decision and area enrolled) of the model.

We tested four hypotheses in each hurdle model (e.g. Treatment 1 vs Control and Treatment 2 vs Control in both enrolment decision and enrolled area model parts), so we used Bonferroni correction for multiple testing and thus considered p-values below 0.0125 as significant for direct effects of treatment in both parts of the model. As covariates and interactions were used for control and exploratory purposes, we did not adjust the p-value for them and used p=0.05 as the statistical significance threshold.

After running regression models, average marginal effects of treatments were estimated for all models. Additionally, plots of average predicted probabilities were produced for all interaction terms to compare the effects of treatment in different population subgroups.

RESULTS

Experiment 1

In 2023, only 111 out of 4,357 farmers enrolled into the Skylark scheme, together providing plots on 1,004.3 ha of arable land. In gain treatment (1,437 farms), 32 farmers enrolled 442.0 ha, in loss treatment (1,460 farms) 35 farmers enrolled 275.0 ha and in the control group (1,460 farms), 44 farmers enrolled 292.0 ha of land. 220 farmers who received the letter did not submit their subsidy application. There were no statistically significant differences in the socio-demographic and farm-related characteristics of the three experimental groups. Three-sample test of equal proportions showed no statistically significant differences in enrolment rates between the three treatment groups ($x2 = 2.16$, df = 2, p-value = 0.339), while Kruskal-Wallis test shows that there were also no statistically significant differences in area enrolled among the three groups ($x2 = 2.12$, df = 2, p-value = 0.347).

Table 2: Hurdle regression model results for Experiment 1.

	Zero-inflated		**Conditional**	
	Estimate	**P-value**	**Estimate**	**P-value**
(Intercept)	0.07	0.866	0.73	0.153
Gain framing	0.25	0.183	-2.06	0.047
Loss framing	0.05	0.745	-1.61	0.052
Eligible arable land	0.03	**<0.001**	0.04	**<0.001**
Age	0.01	0.359	0.00	0.766
Gender - Female	0.23	0.274	0.01	0.975
AECM - Yes	0.80	**<0.001**	0.15	0.571
LU/ha	-0.07	0.531	-0.01	0.933
Gain:eligible arable land			-0.02	**0.026**
Loss:eligible arable land			-0.02	**0.007**
Gain:Age			0.03	0.056
Loss:Age			0.02	0.067
Gain:Female			1.85	**0.004**
Loss:Female			-0.19	0.631
Gain:AECM			1.31	**0.017**
Loss:AECM			1.40	**<0.001**
Gain:LU/ha			-0.13	0.587
Gain:LU/ha			-0.30	0.147

In the hurdle model (Table 2), neither treatment had a statistically significant effect on the decision to enrol and average marginal effects were similarly small (-1.23% (95% CI -2-56,-0.11) for gain and and -0.03% (95% CI -1.74,1.20) for loss framing, respectively). After correcting for multiple hypothesis testing (a = 0.0125), treatments do not have statistically significant effects on enrolled area despite the large average marginal effects (-226 ha (95% CI -974,522) for gain and -232 ha (95% CI -980, 516) for loss treatment, respectively). However, multiple interactions were statistically significant, including between gain framing and gender, and between both types of framing and enrolment in AECM and eligible arable land, all of which were affecting the amount of land enrolled, but not enrolment decision (Table 2). Plots of average marginal effects for all interaction terms, shown in Fig. 1A, point to a lack of differences in effect sizes between treatment groups in most population subsamples. However, those who received gain or loss framed letters enrolled on average about 5 ha more land in the Eco-scheme if they were also enrolled in AECM, while there was no such difference for control group. Additionally, women who received gain-framed letter enrolled about 6 ha of land more on average than any other group of participants. Looking at the direct effects of covariates, enrolment in AECM is statistically significantly positively associated with enrolment in the Skylark scheme, while the amount of eligible arable land has a statistically significant positive effect on both enrolment and the amount of land enrolled (Table 2).

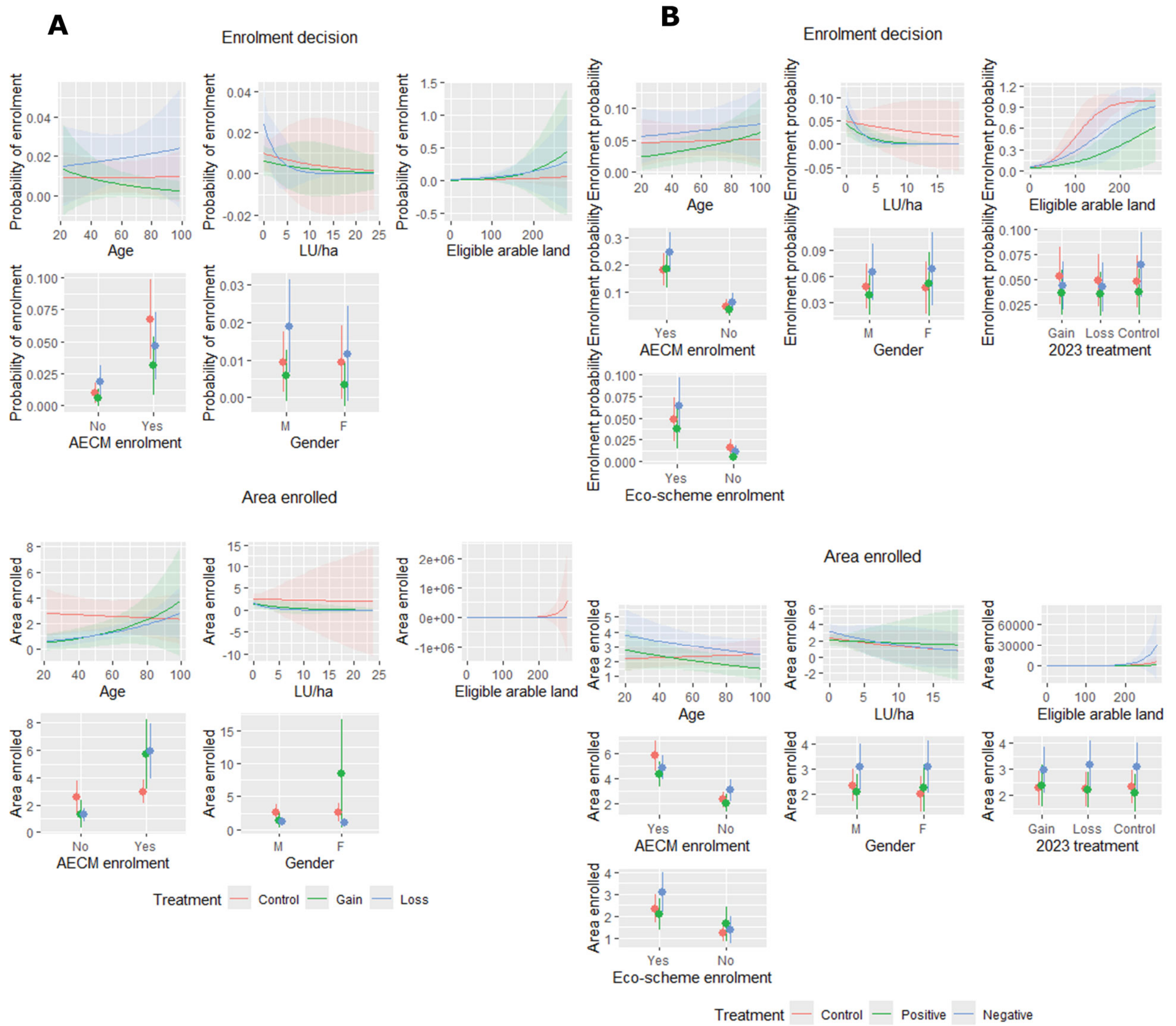

Figure 1. Average marginal effects of treatment in Experiment 1 (A) and Experiment 2 (B), depending on each covariate in the model. The upper part of the figure, "Enrolment decision", corresponds to the zero-inflated part of the hurdle regression model where probability of enrolment is the likelihood on a scale from 0 to 1, while the lower part, "Area enrolled", corresponds to the conditional part of the hurdle regression model and area enrolled is measured in hectares.

Table 3: Hurdle regression model results for Experiment 2.

	Zero-inflated		**Conditional**	
	Estimate	**P-value**	**Estimate**	**Pr(>|z|)**
(Intercept)	-4.32	<0.001	-0.10	0.744
Positive norm	-1.57	0.106	1.00	0.038
Negative norm	-0.76	0.397	0.45	0.331
Gender - F	-0.05	0.854	-0.15	0.231
Age	-0.00	0.852	0.00	0.680
LU/ha	-0.06	0.630	-0.06	0.456

AECM - Yes	1.47	**<0.001**	0.91	**<0.001**
Eco-schemes - Yes	1.15	**<0.001**	0.63	**<0.001**
Eligible arable land	0.03	**<0.001**	0.03	**<0.001**
2023 Loss framing	-0.09	0.712	-0.02	0.898
2023 Control	-0.11	0.664	0.03	0.807
Positive norm:AECM	0.28	0.491	-0.16	0.442
Negative norm:AECM	0.08	0.843	-0.45	**0.024**
Positive norm:Other Eco-schemes	0.79	0.103	-0.40	0.122
Negative norm:Other Eco-schemes	0.71	0.122	0.19	0.443
Positive norm:eligible arable land	-0.02	**0.012**	-0.01	0.109
Negative norm:eligible arable land	-0.01	0.114	0.00	0.232
Positive norm:Female	0.36	0.348	0.23	0.264
Negative norm:Female	0.11	0.775	0.16	0.400
Positive norm:Age	0.01	0.368	-0.01	0.139
Negative norm:Age	-0.00	0.824	-0.01	0.231
Positive norm:LU/ha	-0.24	0.295	0.04	0.710
Negative norm:LU/ha	-0.44	**0.036**	-0.02	0.879
Positive norm:2023 loss	0.06	0.868	-0.06	0.758
Negative norm:2023 loss	0.07	0.855	0.09	0.639
Positive norm:2023 contol	0.14	0.712	-0.16	0.385
Negative norm:2023 control	0.52	0.140	0.01	0.951

Experiment 2

In 2024, 292 farms enrolled 3,020 ha into the Skylark scheme out of 4,376 farmers that submitted their general CAP subsidy application. 172 farmers (out of 4,548 farmers that received a letter in total) did not submit their subsidy application. While the total share of farmers (6.7%) and land enrolled into the scheme (7% of eligible arable land) still remains low, the enrolment rate almost tripled compared to 2023.

In this trial, 83 farmers receiving positive descriptive norms enrolled 815 ha, 98 farmers receiving negative descriptive norms enrolled 865 ha and 111 farmers from the control group enrolled 1,339 ha. There were no statistically significant differences in the characteristics of the three experimental groups. The three sample test of equal proportions showed that there are no statistically significant differences among the three treatment groups in terms of enrolment rates (x2 = 4.18, df = 2, p-value = 0.124), while Kruskal-Wallis test showed no statistically significant differences in area enrolled among the three groups (x2 = 4.30, df = 2, p-value = 0.117).

In the hurdle regression model, there were again no direct statistically significant effects of our treatments neither on enrolment decision (average marginal effect for positive treatment: -1.95% (95% CI -3.85,0.06); for negative treatment: -0.66% (95% CI -2.58,1.26)) nor on area enrolled (statistically insignificant average marginal effect for positive treatment: -4.25 ha (95% CI -10.9,2.34), for negative treatment = 12.27 ha (95% CI -14.1,38.59)) (Table 3). However, positive norm statistically significantly interacted with eligible arable land and there was also a statistically significant interaction between negative norm and livestock unit per ha, both negatively affecting the decision to enrol. Finally, those who received negatively-framed message and were enrolled in AECM enrolled statistically significantly less land (Table 3). The average marginal effects of all interactions, displayed in Fig. 1B, show that within different population subgroups, the effects of the different treatment groups were similar. The most prominent difference in marginal effects among the treatment groups is for eligible arable land, where enrolment proba-bility increases much faster for the control group than for the positively framed group and is thus around 60% higher in the control group for farms with around 150 ha of eligible arable land (Fig. 1B). Among the covariates, enrolment in AECM and other Eco-schemes and more eligible arable land were consistently statistically significantly positively associated with both enrolment decision and the amount of land enrolled (Table 3).

DISCUSSION

Recent economic research has increasingly emphasized the role of behavioural factors in shaping farmers' decisions to adopt environmentally sustainable practices (Dessart et al., 2019). This behavioural perspective offers a foundation for designing interventions particularly through information framing that aim to improve enrolment in agri-environmental schemes (Chabé-Ferret et al., 2023). Despite growing interest in such nudges, evidence regarding their effectiveness remains mixed and inconclusive (Mertens et al., 2022).

In our first experiment, we found no statistically significant overall effect of gain or loss framing on enrolment in the Skylark scheme. This result contrasts with previous literature, which has generally found positive effects of such framing (Ropret Homar and Knežević Cvelbar, 2021). The negative direction of effects observed in our interaction model was therefore unexpected but given their insignificance could result from random variation.

Our exploratory analysis revealed several statistically significant interactions, particularly concerning the amount of land enrolled. These findings suggest that the impact of framing may depend on farm-specific characteristics. First, both gain and loss framing showed negative interactions with the amount of eligible arable land, deviating from the commonly reported positive effect of framing interventions. This may indicate that larger farms typically more commercially oriented and strategic in their decision-making (Bojnec and Latruffe, 2013) may perceive conservation-oriented messages as misaligned with their economic objectives. Tailored interventions that better align with the operational realities and incentives of large farms may be more effective in increasing their participation.

Second, we identified a positive and statistically significant interaction between prior enrolment in AECM and exposure to either gain or loss framing: farmers with AECM experience enrolled, on average, 5 additional hectares in the Skylark scheme. This enhanced responsiveness to nudges among AECM participants was consistent across both experiments, as evidenced by a statistically significant negative interaction between negative descriptive norms and AECM enrolment in Experiment 2. Moreover, AECM participation independently and positively influenced both enrolment probability and the area enrolled in both trials. These findings are consistent with the view that AECM participants often hold more pro-environmental attitudes and are more aware of farming's ecological impacts (Dessart et al., 2019; Klebl et al., 2023), making them more receptive to conservation messages.

We also observed a significant gender-based interaction: women exposed to gain-framing messages enrolled, on average, 6 hectares more than their male counterparts. Although few studies have examined gender differences in response to framing, existing findings are either neutral (Ezquerra et al., 2018) or suggest that women are more sensitive to loss framing (Cochard et al., 2020). The reverse effect found in our study warrants further investigation to understand its underlying drivers.

In the second experiment, descriptive norm framing overall also had no statistically significant effect on enrolment. Interestingly, while both positive and negative frames showed negative effects on enrolment probability, they were positively associated with the area enrolled. Previous research typically shows that positively framed norms have beneficial effects, while negatively framed norms tend to be neutral or detrimental (Cialdini et al., 2006; Mollen et al., 2021). One potential explanation why both frames had the same direction of the effect is that farmers may have focused more on the actual enrolment figures identical in both versions rather than on the descriptive framing.

Despite the lack of overall treatment effects, we observed some noteworthy interactions. A statistically significant negative interaction between livestock density (LU/ha) and negative framing suggests that this nudge backfired among more intensive farms. Similarly, a negative interaction between positive framing and eligible arable land was identified. These results may reflect a "boomerang effect," where large farms interpret the framing as misrepresentative or unconvincing, particularly if they alone could account for a substantial portion of total enrolment. Such outcomes underscore the risks of using social norm messages in contexts where the desired behaviour is not yet widespread (Chabé-Ferret et al., 2023; Cialdini et al., 2006).

While the actual share of eligible land used in the Skylark scheme may be underestimated due to crop suitability constraints, the observed enrolment rates (2% and 7% in Experiments 1 and 2, respectively) suggest substantial room for improvement. Our findings indicate that information framing alone is unlikely to significantly increase enrolment unless it addresses other barriers farmers face. Prior studies have identified concerns such as potential yield loss, weed proliferation, and more difficult cultivation as key deterrents (Alif et al., 2024). Additionally, the offered payment of €60/ha may not sufficiently compensate for the perceived risks and effort required to participate. Future research should investigate these structural and economic barriers to identify the primary bottlenecks limiting scheme uptake.

CONCLUSIONS

The two experiments presented here are among the first randomized controlled trials evaluating agricultural policy nudges in a European context (Chabé-Ferret et al., 2023). A key strength of our study lies in its real world implementation: farmers were unaware that the Ministry collaborated with researchers or that the letters they received had been experimentally manipulated. Moreover, the trials were conducted at the national level, encompassing the full population of eligible farmers and minimizing sample selection bias.

We tested the effect of two behavioural nudges gain/loss framing and descriptive norms on enrolment in a new Eco-Scheme. Overall, no statistically significant effects were found at the population level. However, treatment effects emerged among specific subgroups, particularly farmers with AECM experience, those re-enrolling in the scheme, those with large areas of eligible land, women, and farmers with high livestock density. Our findings high-light the importance of audience segmentation and the contextual sensitivity of behavioural interventions. Policy strategies aiming to enhance AES participation should therefore consider targeted, tailored approaches rather than relying solely on broad-based nudges (Hawkins et al., 2008).

Finally, the low enrolment rates suggest that behavioural interventions alone may not suffice. Addressing practical concerns such as production risks and administrative burdens and considering enhancements to scheme design or payment levels may be necessary to drive more widespread adoption. Moreover, given the potential for nudges to backfire under certain conditions, their application must be carefully considered within the specific agricultural and socio-economic context (Chabé-Ferret et al., 2023; Chater and Loewenstein, 2023).

ACKNOWLEDGEMENT

We would like to thank the Ministry of Agriculture, Forestry and Food of Republic of Slovenia for their cooperation and support in conducting the two studies presented in this paper. This study was supported by the Slovenian Research Agency under grant P4-0022 (B) and the Ministry of Agriculture, Forestry and Food under grant CRP V4-2020. T. Šumrada's work was co-funded by the European Union - NextGeneration EU research project (public call C3.K8.IC).

REFERENCES

Alliance Environment (2019). Evaluation of the impact of the CAP on habitats, landscapes, biodiversity: final report. European Commission. Directorate General for Agriculture and Rural Development., LU.

Bojnec, Š. and Latruffe, L. (2013). Farm size, agricultural subsidies and farm performance in Slovenia. Land Use Policy 32: 207–217.

Chabé-Ferret, S., Le Coent, P., David-Legleye, V. and Delannoy, V. (2023). Non-monetary incentives to increase enrollment in payments for environmental services. European Review of Agricultural Economics 50: 1401–1427.

Chater, N. and Loewenstein, G. (2023). The i-frame and the s-frame: How focusing on individual-level solutions has led behavioral public policy astray. Behavioral and Brain Sciences 46: e147.

Cialdini, R.B., Demaine, L.J., Sagarin, B.J., Barrett, D.W., Rhoads, K. and Winter, P.L. (2006). Managing social norms for persuasive impact. Social Influence 1: 3–15.

Cochard, F., Flage, A., Grolleau, G. and Sutan, A. (2020). Are individuals more generous in loss contexts? Soc Choice Welf 55: 845–866.

Dessart, F.J., Barreiro-Hurlé, J. and van Bavel, R. (2019). Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. European Review of Agricultural Economics 46: 417–471.

Ezquerra, L., Kolev, G.I. and Rodriguez-Lara, I. (2018). Gender differences in cheating: Loss vs. gain framing. Economics Letters 163: 46–49.

Feng, C.X. (2021). A comparison of zero-inflated and hurdle models for modeling zero-inflated count data. Journal of Statistical Distributions and Applications 8: 8.

Ferraro, P., Messer, K.D. and Wu, S. (2017). Applying Behavioral Insights to Improve Water Security. Choices 32: 1–6.

Hasler, B., Termansen, M., Nielsen, H.Ø., Daugbjerg, C., Wunder, S. and Latacz-Lohmann, U. (2022). European Agri-environmental Policy: Evolution, Effectiveness, and Challenges. Review of Environmental Economics and Policy 16: 105–125.

Hawkins, R.P., Kreuter, M., Resnicow, K., Fishbein, M. and Dijkstra, A. (2008). Understanding tailoring in communicating about health. Health Education Research 23: 454–466.

Kahneman, D. and Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. Econometrica 47: 263–291.

Klebl, F., Feindt, P.H. and Piorr, A. (2023). Farmers' behavioural determinants of on-farm biodiversity management in Europe: a systematic review. Agric Hum Values 2024: 831–861.

Mertens, S., Herberz, M., Hahnel, U.J.J. and Brosch, T. (2022). The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioral domains. Proceedings of the National Academy of Sciences 119: e2107346118.

Michie, S., Johnston, M., Francis, J., Hardeman, W. and Eccles, M. (2008). From Theory to Intervention: Mapping Theoretically Derived Behavioural Determinants to Behaviour Change Techniques. Applied Psychology 57: 660–680.

Mollen, S., Holland, R.W., Ruiter, R.A.C., Rimal, R.N. and Kok, G. (2021). When the Frame Fits the Social Picture: The Effects of Framed Social Norm Messages on Healthy and Unhealthy Food Consumption. Communication Research 48: 346–378.

Pe'er, G., Finn, J.A., Díaz, M., Birkenstock, M., Lakner, S., Röder, N., Kazakova, Y., Šumrada, T., Bezák, P., Concepción, E.D., Dänhardt, J., Morales, M.B., Rac, I., Špulerová, J., Schindler, S., Stavrinides, M., Targetti, S., Viaggi, D., Vogiatzakis, I.N. and Guyomard, H. (2022). How can the European Common Agricultural Policy help halt biodiversity loss? Recommendations by over 300 experts. Conservation Letters 2022: e12901.

Ropret Homar, A. and Knežević Cvelbar, L. (2021). The effects of framing on environmental decisions: A systematic literature review. Ecological Economics 183: 106950.

Schulze, C., Zagórska, K., Häfner, K., Markiewicz, O., Czajkowski, M. and Matzdorf, B. (2024). Using farmers' ex ante preferences to design agri-environmental contracts: A systematic review. Journal of Agricultural Economics 75: 44–83.

Thaler, R.H. and Sunstein, C.R. (2008). Nudge: Improving Decisions about Health, Wealth, and Happiness. Yale University Press.

Croatian Pork Meat Market Outlook and Analysis of Monthly Remainders in Pig Fattening

Aleksandra Berić[1], Krunoslav Zmaić[2], Ana Crnčan[2] and David Kranjac[2]

[1] Postgraduate university student of doctoral studies, majoring in "Agroeconomics", Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University in Osijek, Vladimira Preloga 1, Osijek, Croatia (aberic@fazos.hr)

[2] Josip Juraj Strossmayer University in Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia

ABSTRACT

Pork meat production is one of the key sectors of agricultural production in the Republic of Croatia, playing a significant role in ensuring domestic meat supply and supporting rural economic activity. However, in recent years, particularly in the period from 2020 to 2023, the sector has been facing persistent negative indicators and structural challenges. These difficulties come from strong market volatility, high input costs (feed, energy), and simultaneously low purchase prices which have contributed to reduced production stability. Crises such as the COVID-19 pandemic, the war in Ukraine, and the outbreak and spread of African Swine Fever have further exacerbated the sector's vulnerabilities. This paper provides a balance sheet overview of the Croatian pig production sector since Croatia's accession to the EU and an analysis using the Monthly Remainders Methodology, with the aim of identifying the key trends and changes in the sector's performance and explaining why these have deteriorated during the 2020 to 2023 period.

INTRODUCTION

Despite favourable natural conditions, the availability of resources, and a long-standing tradition of pig farming, the pig production sector in the Republic of Croatia has been facing numerous structural and market-related challenges, particularly since the country's accession to the European Union in 2013. Although deeply rooted in rural areas, especially in Eastern Croatia, this sector has been experiencing a continuous decline in production capacity and competitiveness compared to other EU member states (Kranjac et al., 2018; Grgić et al., 2019).

A comparison of sectoral indicators from 2013 and 2023 reveals clear negative trends, most notably a decline in the number of sows and pigs across all categories, indicating a long-term downward trajectory in production (Table 1).

Table 1. Number of different categories of pigs in the Republic of Croatia (2013 – 2023)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs 2013
Piglets and pigs from 20 to 50 kg (000 head)	518	595	526	557	511	502	444	464	434	383	375	-27.5%
Pigs for fattening (000 head)	465	442	519	483	482	423	451	456	431	474	391	-16.1%
Pigs for breeding (000 head)	128	119	122	122	128	124	128	113	107	87	87	-32.0%
Pigs total (000 head)	1111	1156	1167	1163	1121	1049	1022	1033	971	944	853	-23.2%

Source: Croatian Bureau of Statistics 2013-2023

Changes in demand, increased competition within the EU single market, and growing pressure on the economic sustainability of production have further worsened conditions on the domestic pork market. Between 2013 and 2023, pork meat production in Croatia increased modestly by 5.5%, while domestic consumption rose by over 40%, highlighting a growing dependence on imports. Imports surged by 68.5% over the same period. Consequently, the trade deficit in pork deepened, with net exports deteriorating by 57.4%, reflecting the sector's declining self-sufficiency and competitiveness (Table 2).

Table 2. Pork meat market outlook in the Republic of Croatia (2013 – 2023)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs. 2013
Pork meat production (1000 t)	106,8	95,8	94,0	104,9	118,3	129,7	134,8	125,3	122,5	129,5	112,6	5.5%
Domestic consumption (1000 t)	148,2	155,9	160,5	166,3	173,7	193,6	197,3	188,6	209,4	226,2	210,2	41.8%
Imports (1000 t)	60,64	75,96	86,13	81,34	86,16	87,53	83,54	84,86	94,31	102,9	102,2	68.5%
Exports (1000 t)	1,55	3,35	7,03	9,41	7,04	7,44	7,08	6,65	7,40	12,62	9,23	495,5%
Net Exports (1000 t)	-59	-72,6	-79,1	-71,9	-79,1	-80,1	-76,5	-78,2	-86,9	-90,4	-93	-57,4%

Source: Croatian Bureau of Statistics 2013-2023

Figure 1 illustrates the self-sufficiency rate in pig meat production in Croatia compared to the European Union average from 2013 to 2023. While the EU has maintained a consistently high level of self-sufficiency exceeding 100% throughout the observed period, Croatia's self-sufficiency has shown a continuous downward trend. This divergence highlights the increasing structural vulnerability and declining domestic capacity of the Croatian pig sector.

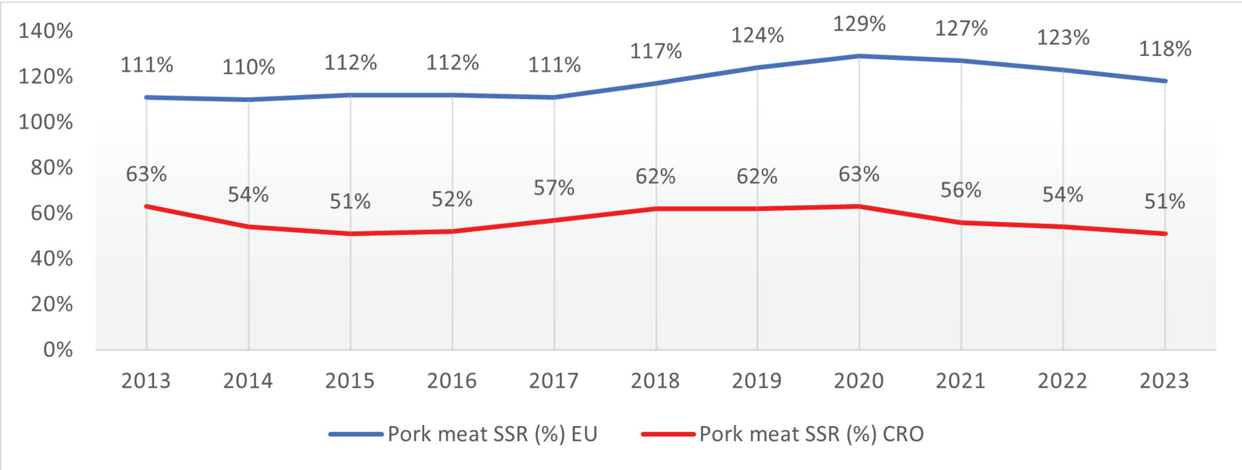

Figure 1. Comparison of pork meat self-sufficiency in the EU and Croatia (2013 – 2023)
Source: Croatian Bureau of Statistics, EUROSTAT 2013-2023

Since 2020, the sector has been additionally destabilised by a series of external shocks. The outbreak of the COVID-19 pandemic caused significant disruptions in supply chains and led to pork surpluses, which dramatically reduced purchase prices. Although pork prices began recovering in early 2022, producers did not experience financial relief due to the surge in input costs, driven by inflation and the rise in energy prices caused by the war in Ukraine (Sohag et al., 2023). Prices of cereals and animal feed increased significantly, while elevated piglet prices throughout 2023 placed further pressure on producers' profitability.

During the same period, the sector was also affected by the outbreak of African Swine Fever (ASF), which further disrupted production, restricted the movement of live animals, and undermined investment security. The combination of market volatility, cost increases, and animal disease outbreaks has deepened already existing negative trends and threatens the long-term sustainability of pig production in the Republic of Croatia (Kranjac et al., 2020; Grgić et al., 2016).

MATERIAL AND METHODS

The monthly remainders methodology is an established analytical tool developed and applied by the European Commission's Meat Market Observatory under DG AGRI. Its primary purpose is to monitor and analyse key production input factors in the pig sector across the European Union (EU). The methodology allows for the calculation of the remaining margin (remainder) left to producers after deducting the cost of basic production inputs from the average monthly carcass price of pigs.

The basic production inputs considered in the calculation include the cost of compound feed ingredients and piglet prices, which are analysed alongside monthly pig carcass prices. The average monthly price of feed ingredients is derived from the weighted average of monthly prices of cereals (feed barley, wheat, and maize) and soybean meal, with cereals accounting for 85% and soybean meal for 15% of the feed composition. All price data including piglet, feed, and carcass prices were obtained from the DG AGRI commodity price monitoring platform (Monthly Commodity Dashboard).

In addition to input prices, the methodology incorporates key parameters of the pig fattening cycle. Some of these parameters are fixed, such as the initial piglet weight, average daily gain, fattening duration, feed conversion ratio, and carcass yield. Others are calculated values, including the final weight of the fattened pig, carcass weight, and required feed quantity per 100 kg of carcass weight.

Based on this methodology, a comprehensive overview was created for the average monthly prices of feed, piglets, carcasses, and the calculated monthly remainder (in EUR) left to producers in the Republic of Croatia for the period from 2020 to 2023.

The following parameters are used in the calculation of monthly remainders in pig fattening:

- Initial piglet weight (IPW, kg) = fixed = 25.00
- Average daily gain (ADG, kg) = fixed = 0.80
- Fattening duration (days) = fixed = 121.7
- Feed conversion ratio (kg gain/kg feed) = fixed = 3.00
- Carcass yield (CY, index) = fixed = 0.78
- Final weight (FW, kg) = calculated = IPW + (ADG × fattening duration)
- Carcass weight (CW, kg) = calculated = FW × CY
- Feed requirement (FR, kg per 100 kg carcass) = (ADG × fattening duration × conversion ratio) × 100 / CW
- Feed composition = fixed
- Average feed price (AFP, EUR/kg) = monthly feed price × share of component in the feed
- Feed cost (FC, EUR/100 kg carcass) = AFP × FR
- Piglet price (PP, EUR/head) = fixed
- Piglet cost per 100 kg carcass (PC, EUR) = PP × 100 / CW
- Carcass price (CP, EUR/100 kg) = average of S, E, and R classes
- Monthly remainder (EUR/100 kg carcass) = CP – (FC + PC)

RESULTS

The analysis of monthly producer remainder in pig fattening in the Republic of Croatia from 2020 to 2023 reveals pronounced market disruptions and cost pressures, particularly in the wake of pandemic and war-induced shocks. Figure 2 shows monthly average carcass prices (S+E classes), feed costs, piglet prices, and the calculated producer remainder (margin) per 100 kg of carcass. The beginning of the year 2020 was still relatively stable, despite the onset of the COVID-19 pandemic in early spring. The full effects of pandemic-related market disruptions did not materialize until the last quarter of the year, when carcass prices began to decline sharply indicating the emergence of surplus volumes on the EU single market.

In 2021, the sector entered a pronounced crisis phase. Average annual feed costs increased by 34.5% compared to 2020, while carcass prices declined by 17%. These dynamics significantly eroded profitability, with the producer remainder dropping by more than 60%. Monthly data show that throughout much of 2021, margins were critically low or negative, especially in the second half of the year.

Although carcass prices began recovering in early 2022, this did not result in a recovery of producer remainders. The main limiting factor was the surge in feed costs triggered by the outbreak of war in Ukraine. Compared to 2020, feed costs in 2022 were nearly twice as high, while the average annual producer remainder was just 20.51 EUR per fattened pig, lower than in 2021. This suggests that the increase in output prices was insufficient to compensate for extreme input cost inflation.

The year 2023 was also characterized by elevated production costs. Feed prices remained high (64.5% above 2020 levels), and piglet prices surged dramatically by 120.4% compared to 2020. However, a strong increase in carcass prices throughout much of the year (up 34.6% compared to 2020) provided partial relief. The average annual producer remainder rose to 37.34 EUR per pig, marking a modest recovery but still far from sustainable margins.

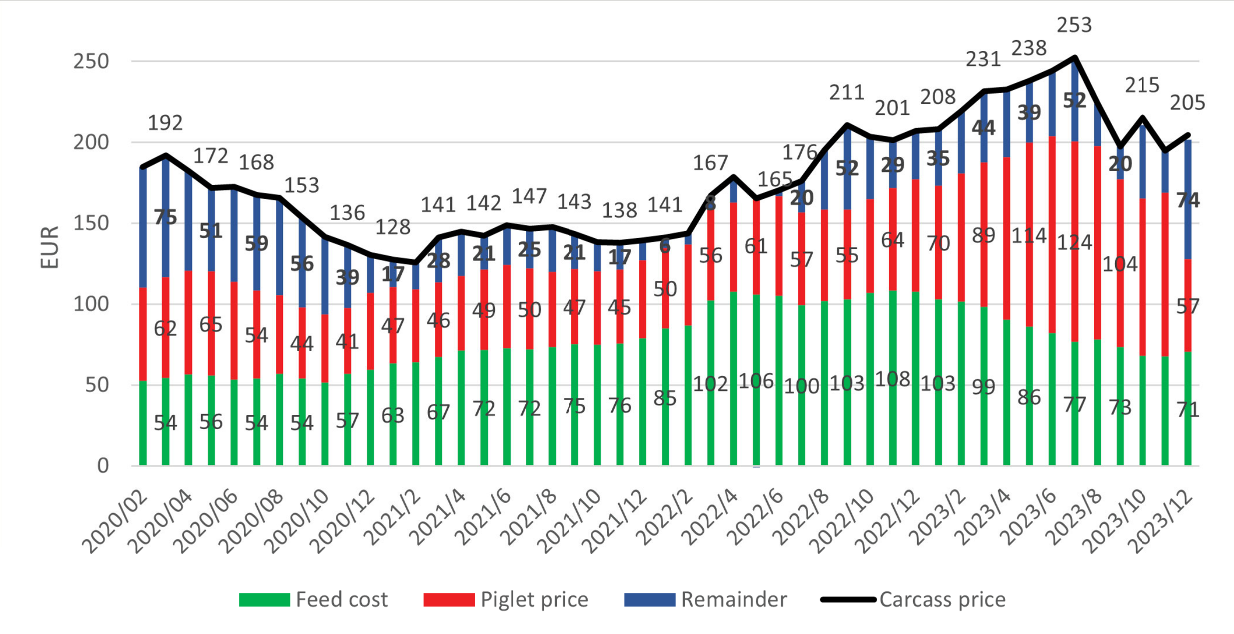

Figure 2. Monthly producer remainder in pig fattening in the Republic of Croatia from 2020 to 2023.

Source: Author's calculation according to DG AGRI - Monthly commodity dashboard

Between 2020 and 2023, there was a marked increase in average carcass prices and piglet prices, particularly in 2023, when the piglet price nearly doubled compared to 2020. Feed costs peaked in 2022, followed by a slight decrease in 2023 (Table 3). The "Remainder" value, which reflects a form of margin or profitability indicator, showed a significant drop in 2021 and 2022, but partially recovered in 2023. This suggests that despite high input costs, better market prices for carcasses helped improve returns in 2023.

Table 3. Comparative display of average values by year (2020–2023)

Year	Feed cost	Piglet price	Remainder	Carcass price
2020	54.75	53.42	57.33	165.58
2021	71.67	47.17	21.25	140.33
2022	101.75	57.75	20.50	180.00
2023	83.08	98.08	40.17	221.83

Source: Author's calculation

DISCUSSION

The results confirm that the Croatian pig production sector has undergone a period of significant deterioration between 2013 and 2023, both in terms of structural capacity and economic viability. The decline in the number of breeding animals, persistent reduction in total pig stock, and increasing import dependency clearly point to a long-term erosion of production potential. This structural weakening is mirrored in the decline of Croatia's self-sufficiency rate, which has fallen sharply even as the EU average remains stable.

The producer margin analysis based on the monthly remainders methodology further reveals that this deterioration is not only structural but also strongly influenced by external cost and price shocks. The most critical period, as shown, was 2021–2022, when producers faced the dual burden of sharply increased feed prices and only modest carcass price recovery, leading to unsustainably low margins. Although 2023 brought a moderate recovery in the sector, it was driven largely by favourable market prices rather than underlying cost reductions or productivity improvements suggesting a fragile and uncertain recovery.

In this context, it becomes evident that the Croatian pig sector lacks resilience and is heavily exposed to input price volatility, particularly in feed and piglet markets. Compared to more integrated or vertically coordinated systems in other EU countries, Croatian production is still fragmented, undercapitalized, and technologically underdeveloped. Moreover, the impact of external crises (e.g., COVID-19, the war in Ukraine, and ASF outbreaks) has been magnified in Croatia by the absence of adaptive support mechanisms, structural investment, and long-term policy orientation.

Importantly, the growing trade deficit and rising domestic consumption underline a serious food security issue. The inability to meet domestic demand despite favourable agro-climatic conditions raises questions about policy effectiveness and the alignment of CAP support instruments with national priorities. Current trends suggest that without targeted intervention particularly in breeding herd recovery, technology adoption, and risk management the sector may continue to decline, further undermining rural development and national meat supply chains.

Future policy directions must therefore focus not only on short-term crisis relief but also on long-term restructuring. This includes incentivizing genetic improvement, fostering producer cooperatives, modernizing farm infrastructure, and improving market access. At the same time, national authorities should work more closely with EU institutions to ensure that rural development measures, environmental schemes, and animal welfare standards do not unintentionally disadvantage small and middle-sized producers who already operate under tight margins.

CONCLUSIONS

The Croatian pig production sector has experienced a sustained decline from 2013 to 2023, marked by significant reductions in pig population, breeding stock, and self-sufficiency. Despite favourable natural and agricultural conditions, the sector's competitiveness has eroded due to structural inefficiencies, limited modernization, and vulnerability to market and external shocks such as the COVID-19 pandemic, the war in Ukraine, and African Swine Fever (ASF).

Economic analysis based on the "monthly remainders" methodology shows that producers faced especially critical conditions in 2021 and 2022, when skyrocketing feed and piglet costs were not matched by carcass prices, resulting in unsustainably low or even negative margins. A partial recovery in 2023 was largely price-driven and remains fragile.

The growing gap between domestic pork production and consumption, alongside a widening trade deficit, highlights an urgent need for strategic policy intervention. Without targeted investments in breeding programs, infrastructure, and risk management, as well as support for producer collaboration and technological adoption, the sector risks further decline.

To ensure long-term sustainability, future policy must balance economic competitiveness with social and environmental goals, aligning EU and national support frameworks to strengthen the resilience, productivity, and food security role of Croatia's pig sector.

REFERENCES

Croatian Bureau of Statistics. (2025). Livestock production data. https://web.dzs.hr/PXWeb/Menu.aspx?px_language=hr&px_type=PX&px_db=Poljoprivreda%2c+lov%2c+%u0161umarstvo+i+ribarstvo

European Commission, DG AGRI. (2025). Monthly commodity price dashboard. https://agridata.ec.europa.eu/extensions/DashboardPrice/DashboardMarketPrices.html

EUROSTAT. (2025). Agricultural production - livestock and meat data. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural production-livestock and meat

Grgić, I., Hadelan, L., Prišenk, J. and Zrakić, M. (2016). Stočarstvo Republike Hrvatske: stanje i očekivanja. Meso 3(8): 256-262.

Grgić, I., Krznar, S. and Bratić, V. (2019). Poljoprivredna proizvodnja Republike Hrvatske prije i nakon pristupanja EU. U: Bilandžija, N., Kovačev, I., ur. Aktualni zadaci mehanizacije poljoprivrede. Zagreb: Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, 487-496.

Kranjac, D., Zmaić, K. and Erjavec, E. (2018). Pregled i perspektiva tržišta svinjskog mesa u Republici Hrvatskoj-simulacija modelom parcijalne ravnoteže. Agroeconomia Croatica 8(1): 75-83.

Kranjac, D., Zmaić, K., Grgić, I., Salamon, P. and Erjavec, E. (2020). Accession impact and outlook for Croatian and EU crop and livestock markets. Spanish journal of agricultural research 18(1): 103.

Sohag, K., Islam, M., Tomas Žiković, I. and Mansour, H. (2023). Food inflation and geopolitical risks: analyzing European regions amid the Russia-Ukraine war. British Food Journal 125(7): 2368-2391.

Analysis of Investments on Agricultural Householding Related to Climate Change Resilience in Slovenia

Ajda Bleiweis and Tanja Travnikar

Kmetijski inštitut Slovenije, (Agricultural Institute of Slovenia), Hacquetova ulica 17, Ljubljana, Slovenia (ajda.bleiweis@kis.si)

ABSTRACT

This article explores climate-related investments co-financed under Measure 4 of Slovenia's Rural Development Programme (RDP) 2014–2022, with a focus on enhancing the resilience of agriculture to climate-related risks. The analysis is based on administrative data comprising 20,645 approved investments, of which 3,664 (29%) were identified as contributing - directly or indirectly - to climate resilience. Using a thematic classification method, the study reveals distinct patterns of investment orientation. Two main groups emerged: (1) frequent, lower-cost operational investments such as slurry tanks, fertilizer and manure spreaders, anti-hail nets, and private irrigation systems; and (2) less frequent, capital-intensive infrastructure investments, including the new construction of cattle housing and protected structures (greenhouses). Additionally, investments in water reservoirs have improved water self-sufficiency and increasing the resilience of farms to weather variability. In total, 96 investments worth EUR 954,512 were approved for the construction or renovation of reservoirs. Additionally, 97 investments worth a total of EUR 901,510 were approved for the arrangement of existing irrigation systems, including modernizations and expansions that enable more efficient and responsive use of water resources. These are strategically important investments for managing weather-related risks such as drought and hail, contributing both to the day-to-day response capacity of farms and to the long-term structural resilience of agricultural production. The findings highlight the importance of evidence-based targeting of public support towards investments with the greatest potential to reduce climate vulnerability and ensure the sustainable transformation of agriculture in increasingly variable conditions.

INTRODUCTION

Climate change is already having a significant impact on many extreme weather and climate events in all regions of the world (IPCC, 2022). Europe is warming faster than the rest of the world, with the average global surface temperature rising by around 1.2°C between 2018 and 2022 compared to the previous period (1850–1900), while in Europe this difference was around 2.2°C (EEA, 2024). Agriculture in the European Union is increasingly facing the impacts of climate change, with more frequent droughts, floods and other extreme weather events threatening farm productivity and stability. According to the European Commission, weather and climate events cause average annual losses exceeding EUR 28 billion in the EU agricultural sector, with droughts accounting for more than half of the damage (European Commission, 2024). Despite these risks, insurance coverage remains low, underscoring the need for proactive adaptation measures. The EU's Common Agricultural Policy (CAP), notably its Rural Development Programme (RDP), supports investments on farms aimed at strengthening climate resilience. Measure 4 of the RDP, which focuses on physical investments, co-finances infrastructure and equipment that help reduce the vulnerability of farms to climate risks and improve resource management including irrigation systems, livestock manure storage facilities and protective structures (European Commission, 2018). Investments of this type are increasingly recognised as key to improving adaptive capacity and ensuring the stability of production in changing weather conditions.

Recent OECD findings highlight the crucial role of scaling up such investments to achieve adaptation goals, especially in sectors such as agriculture, where infrastructure directly reduces exposure to extreme weather events (OECD, 2024). Despite their importance, systematic evaluations of these investments especially in terms of their contribution to climate change adaptation are still limited. Most studies focus on economic or environmental impacts, while fewer studies examine whether and how these investments contribute to long-term resilience (Loboguerrero et al., 2019). Furthermore, knowledge about the typology and distribution of climate-relevant investments is limited, especially based on comprehensive administrative datasets. To address this gap, our study analyses all approved investment applications under Slovenia's RDP 2014–2022, covering the period from 2014 to December 2023. We apply a thematic classification method based on the stated purpose of each investment, identifying those that contribute directly or indirectly to climate adaptation.

This article analyses investments made in agricultural holdings in Slovenia, co-financed under the RDP 2014–2022, which contribute to the adaptation of agriculture to climate change. Based on data on the number of approved investments and the amount of allocated funds, it identifies key investment groups and their focus on strengthening climate resilience. The aim is to shed light on national investment patterns that support agricultural resilience and inform future policy design.

MATERIAL AND METHODS

In the research, we analysed the administrative database from the Ministry of Agriculture, Forestry and Food of all approved investments within the framework of the Rural Development Programme of the Republic of Slovenia 2014–2022 [analysed years from 2014 to December 2023]. The collection includes data on individual applications, such as the name of the investment, the name of the cost, the classification of costs, quantity, unit of measure, approved value and administrative codes.

Based on the substantive descriptions of the investments, we created thematic categories that reflect the main purpose of the individual investment. We further classified them into subcategories, using manual keyword analysis for the most accurate typification possible.

Thematic categories include:

– Agricultural machinery and equipment for fertilisation
– Agricultural machinery and soil cultivation equipment
– Hail protection nets,

- Construction of livestock housing
- Livestock manure storage facilities
- Private irrigation systems and related equipment
- Renewable energy generation on farms
- Protected structures and associated equipment
- Renovation and maintenance of livestock housing
- Establishment of permanent crops with protective measures
- Geothermal energy systems
- Protective film against fruit cracking and sunburn
- Construction of composting platforms
- Construction of small biological wastewater treatment plants (up to 50 PE)

The purpose of the analysis was to identify and evaluate only investments that contribute to the adaptation of agriculture to climate change – either by reducing exposure to weather and climate risks or by improving the management of natural resources, especially water and soil. We included both investments with a direct adaptation effect (e.g. hail protection nets, private irrigation systems, water reservoirs), as well as investments that are primarily intended to mitigate climate change, but also indirectly contribute to adaptation. The latter include, for example, investments in equipment for handling livestock excreta (tanks, spreaders, storage facilities), which enable timely and efficient fertilization even in adverse weather conditions. Such equipment strengthens the resilience of agricultural production to weather extremes and thus significantly contributes to adaptation, which is why we included it in the analysis.

Spatial and energy solutions, such as greenhouses, new housing construction and equipment for heating or energy self-sufficiency, which enable more stable and less weather-dependent production, were also included. Soil tillage machinery and seeders also play an important role in operational adaptation, contributing to better resource use, soil protection and greater adaptability of production.

For data analysis, we used descriptive statistical methods to calculate the number of approved investments and the total approved value by individual categories and subcategories. We also presented the results graphically, with an emphasis on the types of investments that were the most common or received the most financial resources. We paid special attention to the subcategories in terms of their occurrence and financial scope, as they best illustrate the orientations of Slovenian agriculture in adapting to climate change.

RESULTS AND DISCUSSION

By the end of December 2023, 2,543 applications or 20,645 investments had been approved within the framework of the Rural Development Programme 2014–2022, of which 1,613 applications or 3,664 investments were intended to strengthen the resilience of agriculture to climate change. The total value of approved investment funds for the entire period amounted to 177.6 million EUR, of which 29% or 51.5 million EUR was allocated to strengthening climate resilience. Further analysis focuses on this 29% investments.

The analysis was carried out at the level of approved investments and not at the level of approved applications, as a beneficiary can apply for multiple investments with one application (the average number of investments per application during this period was 2.3). Figure 1 shows the distribution of approved funds among the 10 main investment categories. Four minor categories (geothermal energy systems, protective film against fruit cracking and sunburn, construction of composting platforms, construction of small biological wastewater treatment plants - up to 50 PE) have been excluded due to their marginal financial share, as they together account for only 1% of the total approved investment funds. The most frequently supported investments, in terms of number, were technically simple and financially more accessible. The category agricultural mechanization and machinery intended for fertilization dominated, with 1,252 investments and a total approved value of EUR 10.2 million, which represents one third of the investments considered. These investments are particularly suitable for small and medium-sized farms, enabling operational adaptation to changed production conditions. Other commonly supported categories included private irrigation systems and associated irrigation equipment (468 investments), anti-hail nets (447 investments), livestock manure storage facilities (498 investments) and soil cultivation machinery (367 investments). Together, these four categories comprised 1,780 investments or 48.58% of all investments analysed, indicating their central role in the daily response of farms to climate risks such as drought, hail and water pollution.

In terms of the total amount of approved funds, more capital-intensive investments stand out (Figure 1). The highest total value was achieved by the category construction of livestock housing (16.2 million EUR or 31.5% of all investments). This is followed by agricultural machinery and equipment intended for fertilization (10.2 million EUR), followed by private irrigation systems (5.0 million EUR), protected spaces and associated equipment (4.3 million EUR), agricultural machinery for soil cultivation (3.9 million EUR), livestock manure storage facilities (3.6 million EUR) and anti-hail nets (3.2 million EUR). This distribution of investments confirms the presence of two complementary approaches, namely high-frequency, operational and accessible investments and low-frequency, infrastructure and capital-intensive investments. Both groups play a key role in increasing the resilience of the agricultural sector.

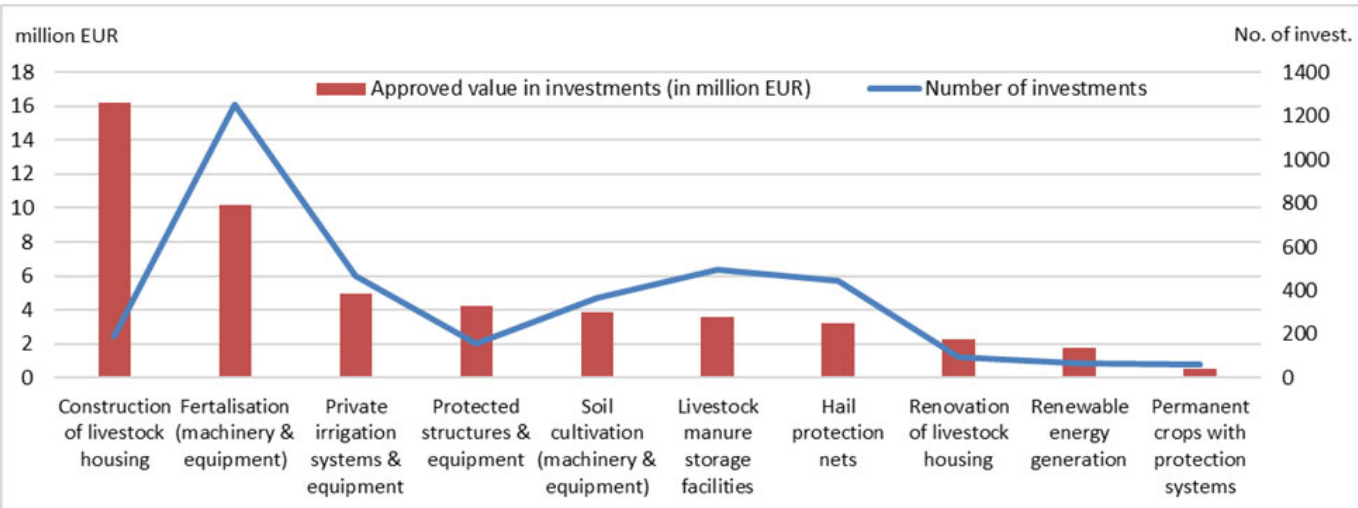

Figure 1. Distribution of investments by categories

Source: Ministry of Agriculture, Forestry and Food of the Republic of Slovenia; Agricultural institute of Slovenia calculations

The results of the subcategories we identified within the above-mentioned categories are presented below. We identified 65 subcategories, but for the main part of the analysis we focused on the first twenty subcategories (top 20) with the highest total value of approved funds, as they represent approximately 87% of the total value of the investments analysed (Table 1).

In first place is New construction of cattle housing with 115 investments and 10.7 million EUR in total approved funds (93,332 EUR per investment), which indicates a highly capital-intensive investment. High average values per investment were also recorded for greenhouses (52,475 EUR), poultry (166,518 EUR) and pig housing (74,325 EUR), which means that these investments are generally accessible to larger and specialized farms.

On the other hand, measures that were common but financially less extensive (EUR/investment) stand out. The most prominent example is slurry tanks (353 investments, 3.2 million EUR), which together with distribution pipes with trailed coulters and trailed pipes represent a comprehensive system for low-emission and targeted application of organic matter and represent 10.5% of all approved funds. It is one of the most important sets of technological adaptation, as it enables responsive nutrient management in the face of changing precipitation and temperature conditions. The installation of anti-hail nets also has a special position (397 investments, 3.0 million EUR), with a relatively high frequency and an average value of 7,434 EUR. Investments in anti-hail nets represent almost 5.7% of all approved funds. These nets represent one of the key measures for reducing exposure to direct weather risks and preventing crop losses due to increasingly frequent hail.

A total of 468 investments worth almost EUR 5 million were approved under the category Private irrigation systems and irrigation equipment. Of this, the majority (199 investments, 1.3 million EUR) were for the purchase of equipment such as pipes, pumps and drip irrigation systems, which indicates a widespread need for technological modernization of basic irrigation functions on farms. A significant part of the funds for private irrigation systems was also allocated for the arrangement of basic infrastructure such as water connections, pressure stations and supply channels (40 investments, 1.3 million EUR). In addition, 97 investments worth a total of 0.9 million EUR were approved for the arrangement of existing irrigation systems, including modernizations and expansions that enable more efficient and responsive use of water resources. Investments in water reservoirs, which are intended to retain rainwater or other water sources for use during dry periods, also play an important role in this group. In total, 96 investments worth 1 million EUR were approved for the construction or renovation of reservoirs, confirming their role in improving water self-sufficiency and increasing the resilience of farms to weather variability. These are measures that are strategically important for managing weather risks such as drought and hail.

Also important are numerous improvements in the management of livestock excreta, especially through the use of manure spreaders (242 investments, EUR 2,480,965) and fertilizers (276 investments, EUR 1,417,295), which enable daily operational adaptation with smaller resources.

Table 1. Distribution of investments by subcategory

	Approved value (EUR)	Approved value (%)	Number of investments	Average investment value (EUR)
Cattle housing - construction of livestock housing	10,733,189	20.8	115	93,332
Greenhouses	3,673,275	7.1	70	52,475
Pig housing - construction of livestock housing	3,418,956	6.6	46	74,325
Slurry tanks	3,222,989	6.3	353	9,130
Hail protection nets	2,951,212	5.7	397	7,434
Seeders for dense or row sowing	2,733,478	5.3	136	20,099
Manure spreaders	2,480,965	4.8	242	10,252
Trailing hose applicators for slurry tanks	2,166,224	4.2	166	13,050
Poultry housing - construction of livestock housing	1,998,223	3.9	12	166,519
Pig housing - renovation of livestock housing	1,448,123	2.8	48	30,169
Fertiliser spreaders - machinery and equipment	1,417,295	2.8	276	5,135
Development of irrigation infrastructure	1,294,235	2.5	40	32,356
Construction of slurry pits with drive-over slab	1,280,329	2.5	67	19,109
Irrigation equipment (private irrigation systems)	1,254,737	2.4	199	6,305
Slurry pit equipment (manure removal systems)	985,978	1.9	233	4,232
Water reservoirs	954,512	1.9	96	9,943
Irrigation system improvements	901,510	1.8	97	9,294
Biomass boilers	753,600	1.5	22	34,255
Seeders (attached units for dense sowing - width 3m)	606,711	1.2	64	9,480
Energy prod. from renewable sources (facilities, equipment)	590,534	1.1	25	23,621
Top 20	44,866,075	87.1	2,704	
Other investments for climate resilience	6,634,992	12.9	960	
TOTAL	51,501,067	100.0		

Source: Ministry of Agriculture, Forestry and Food of the Republic of Slovenia; Agricultural institute of Slovenia calculations

The remaining 13% of investments, which are not separately mentioned in Table 1, do not stand out financially, but they play an important role within the framework of strategies to increase the resilience of agriculture to climate change. For example, these include innovative energy investments such as geothermal energy (1 investment, EUR 387,300), and environmentally-oriented micro-investments, such as the new construction of small biological wastewater treatment plants (up to 50 PE) (17 investments, EUR 16,564) and films to protect fruits from cracking and sunburn (9 investments, EUR 91,676). In the fruit sector, there are sprinkler and anti-salt systems (36 investments, EUR 563,759) and the installation of plantation devices simultaneously with anti-hail nets (57 investments, EUR 556,168), which are a response to increasingly frequent weather extremes.

The analysis highlights the diverse and complex strategies used by agricultural holdings to reduce climate vulnerability. These investments range from simple, short-term investments to capital-intensive infrastructure investments, all contributing to greater resilience (Pret et al., 2025). Broader adoption of such investments, supported by coherent policy and adequate funding, will be essential to ensure the long-term stability and sustainability of Slovenian agriculture.

CONCLUSIONS

The analysis of investments related to the adaptation of agriculture to climate change showed significant differences between the types of investments in terms of their frequency, financial scope and accessibility. By category, the most frequently made investments were in fertilization machinery, mainly in slurry tanks, which were the subject of 353 approved investments. Together with distribution trailed pipes and trailed coulters, these investments represented a comprehensive technological package for targeted, low-emission application of nutrients, which contributed to reducing environmental losses and increasing soil resistance to drought and leaching. Their prevalence and relatively low average value per investment indicate the wide availability and operational applicability of these solutions in practice. In terms of total approved value, investments in new housing construction stand out (190 investments, EUR 16.2 million), among which the subcategory of new housing construction for cattle breeding stood out, where the total approved value was 10.7 EUR million which indicates the important role of infrastructure investments for the long-term adaptation of livestock systems. Investments in new housing construction in poultry farming were also among the highest average values per investment, where it amounted to 166,819 EUR per investment, which indicates a concentration of funds in more technologically demanding industries. On the other hand, the most common investments were hail nets (397), fertilizer spreaders (276), manure spreaders (242), slurry pit and slurry equipment (233), private irrigation systems - equipment (199), where the average values per investment ranged from EUR 4,232 to EUR 10,252, which demonstrates the importance of smaller but numerically widespread investments in increasing the resilience of farms to weather risks.

The analysis confirms that both operational investments enabling rapid response to weather extremes and long-term infrastructure measures are essential for strengthening agricultural resilience. Funding should prioritise measures with the greatest impact on the long-term resilience of agro-ecosystems. Strategic and targeted investments are needed to effectively manage climate risks and support sustainable adaptation (Ortiz-Bobea et al., 2024).

As the analysis covers only co-financed investments under the Rural Development Programme 2014–2022, it does not reflect privately funded or policy unsupported actions. Nevertheless, it provides valuable insight into public support priorities for climate resilience in Slovenian agriculture.

Based on the findings, several recommendations for decision-makers are proposed. First, small-scale operational investments such as slurry tanks, trailing hose applicators for slurry tanks, manure spreaders and anti-hail nets should remain a funding priority, as they enable rapid adaptation and are widely adopted by farms. Second, infrastructure investments such as livestock housing, irrigation systems and greenhouses play a strategic role in long-term resilience and should be supported in a more targeted manner, particularly in regions and sectors most exposed to climate-related risks such as drought and hail. Third, to ensure that public support achieves its intended adaptation outcomes, clear criteria should be developed for assessing the climate resilience potential of proposed projects. Finally, the diversity and technical complexity of the investments suggests a need for stronger advisory services and knowledge transfer mechanisms to support the effective implementation of climate-resilient technologies on farms.

REFERENCES

Loboguerrero, A.M., Campbell, B.M., Cooper, P.J.M., Hansen, J.W., Rosenstock, T. and Wollenberg, E. (2019). Food and Earth Systems: Priorities for Climate Change Mitigation and Adaptation for Agriculture and Food Systems. Sustainability 11(5): 1372.

Josephson, A., Guerra Su, R., Collins, G. and Jacobs, K. (2024). The Economics of Climate Adaptation: An Assessment. arXiv.org, Papers 2411.16893.

Ortiz-Bobea, A., Chambers, R. G., He, Y. and Lobell, D. B. (2024). Large increases in public R&D investment are needed to avoid declines of US agricultural productivity.

European Commission. (2023). Report on the implementation of the adaptation strategy (SWD (2023) 338 final). Brussels, European Commission.

https://data.consilium.europa.eu/doc/document/ST-14650-2023-ADD-1/en/pdf

IPCC. (2022). Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A. and Rama, B., eds. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

OECD. (2024). Climate Adaptation Investment Framework. Paris, France: OECD Publishing.

Pret, D., Dardonville, M., Petit, M. and Martin, G. (2025). Farm Resilience to Climatic Risk: A Review. Agronomy for Sustainable Development 45: 34.

Inclusiveness and Gender Equality: The Case of an Academic Institution

Štefan Bojnec and Patricia Blatnik

Faculty of management, University of Primorska, Izolska vrata 2, 6000 Koper, Slovenia, (stefan.bojnec@fm.upr.si)

ABSTRACT

This paper presents how a structured Gender Equality Plan (GEP) can significantly enhance inclusiveness and fairness within an academic institution. Using the example of the University of Primorska (UP), it highlights key measures undertaken to integrate gender-balanced approaches across hiring, promotion, and decision-making processes. A dedicated project, AGRIGEP, provides additional support through resources, training, mentoring, and collaborative research opportunities that strengthen awareness and accountability. By fostering transparent selection procedures and nurturing inclusive leadership, UP demonstrates that proactive engagement at all levels top and middle management, academic staff, and student bodies can help remove systemic barriers. The shared learning model, supported by ongoing evaluation and monitoring, allows a continuous adjustment of objectives and strategies. Consequently, UP has seen improved representation of underrepresented groups, enhanced participation in governance structures, and an overall shift toward a more equitable institutional culture. This experience underscores how a clearly defined GEP, combined with consistent community engagement, can serve as a blueprint for other universities aiming to make tangible progress toward gender equality and an inclusive academic institution.

INTRODUCTION

The need for balanced and inclusive practices in the higher education space has been continuously growing over the last decade (Lister et al., 2002). Universities are increasingly adopting strategies to ensure equal opportunities regardless of gender or other personal circumstances. The University of Primorska (UP) has therefore embarked on developing and implementing a Gender Equality Plan (GEP), which includes measures for transparent recruitment, fair promotion mechanisms, and greater representation of underrepresented groups in governing bodies and working committees. At the same time, with the goal of continuous improvement, a latest version of the strategy, called GEP 2.0, is already in preparation, building on previous experiences and enhanced recommendations.

A significant support to NES proved to be the Horizon AGRIGEP project Advancing Gender Equality in European Agriculture and Food Systems which offers a platform for collaboration, research, and education focused on integrating the gender perspective into academic and administrative operations. Horizon AGRIGEP (2025a, 2025b) is a pioneering initiative under the Horizon Europe program aimed at integrating gender equality principles across agri-cultural research, innovation, and policymaking in the EU. The project addresses systemic gender imbalances in the agricultural and agri-food sectors, recognizing the pivotal role of women and marginalized groups in sustainable food systems and rural development. Launched in 2024, AGRIGEP brings together a multidisciplinary consortium of universities, research institutions, non-governmental organisations, policymakers, and stakeholders from across Europe (Mazancová, Bojnec, & Kobolak, 2024a, 2024b). The project's core objective is to develop and implement inclusive GEPs tailored specifically for agricultural and food system organizations, ensuring that gender mainstreaming becomes a structural and sustainable component of institutional practice.

AGRIGEP focuses on five key areas: first, capacity building and training delivering gender-sensitive training modules for researchers, farmers, and policymakers to promote awareness and skill development in gender equity. Second, institutional change supporting organizations in co-creating and implementing GEPs, with mechanisms for monitoring progress and embedding gender equality in governance structures. Third, data collection and analysis establishing robust gender-disaggregated data frameworks to assess gender gaps in access to land, finance, education, and leadership roles. Fourth, policy engagement working closely with EU and national authorities to align agricultural and rural policies with gender equality objectives, including the Common Agricultural Policy.

Finally, knowledge sharing and innovation fostering stakeholders and communities of practice and knowledge hubs to exchange best practices, with a focus on innovation in agri-tech, climate-smart agriculture, and sustainable farming. AGRIGEP places a strong emphasis on intersectionality, ensuring that policies and interventions consider the diverse realities of women in rural areas, including vulnerable groups and youth. By the end of the project in 2026, AGRIGEP aims to establish a replicable model for gender equality transformation in agricultural systems, contributing to the EU's broader goals of social inclusion, sustainability, and innovation in rural economies.

This study aims to show how UP, by combining three key approaches reviewing relevant documents, organizing focus groups, and conducting training managed to gain a comprehensive overview of the challenges and successes in implementing the GEP. The main objective of this study was to assess the effectiveness of the measures from the GEP at UP and to investigate the extent to which they contributed to creating an inclusive, fair, and engaged academic community.

MATERIAL AND METHODS

This study employed a multi-method approach, beginning with a systematic review of existing strategic documents, regulations, and reports on the implementation of the GEP at the UP. The evaluation focused on transparent recruitment, equitable promotions, and including underrepresented groups in decision-making. Among the reviewed materials were documents produced as part of the international AGRIGEP project, as these offered insights into best practices drawn from other European research and educational institutions (Bojnec & Blatnik, 2024). When examining these texts, we also considered the European guidelines for implementing GEPs, particularly those emphasizing the regular monitoring of statistical data and the establishment of uniform evaluation criteria.

In the second phase, we identified three groups to provide insights into various levels of university operations: senior management, middle management and professional staff, and students. For each group, we organized focus groups at various university locations between October 2024 and May 2025. The discussions were recorded and noted. The collected data were subsequently analysed using thematic analysis, with an emphasis on identifying recurring patterns and shared challenges connected to implementing the GEP. Through stakeholder mapping and self-evaluation, we also explored any differences attributable to specific organizational units and their specialized activities.

In parallel with conducting focus groups, we held training sessions and workshops for both senior administrative personnel and professional staff, as well as for students. The content of the training centred on recognizing and mitigating unconscious biases and on strengthening the skills needed to integrate gender equality principles into everyday work and decision-making processes. The workshops employed a methodology devised by the AGRIGEP network, particularly in regions where successful practices had been identified at other European universities (Mazancová, Bojnec, & Kobolak, 2024a). By distributing surveys among international students, we also introduced a cross-cultural dimension into the analysis to determine how receptive the university environment is to the diverse cultural contexts and needs of its international student body.

In the final phase, we synthesized findings from the various methods. Combining survey data, document reviews, and focus group insights enhanced the reliability of the findings through triangulation. Efforts focused on identifying differences between faculties, especially regarding administrative resources, financial resources, and readiness to implement gender equality changes. This approach provided a comprehensive view of the effectiveness of the current GEP and of the specific challenges that inform the formulation and implementation of the GEP 2.0 strategy.

RESULTS

The analysis of the reviewed documents, including key strategic acts, regulations, and reports on the implementation of the GEP, revealed that the UP is gradually moving toward more transparent and inclusive policies, particularly in the areas of hiring and promotion for academic and professional staff. Several documents provided guidelines for forming various committees and establishing mentoring programs, indicating efforts to address systemic barriers. At the same time, some gaps emerged, such as the lack of uniform methods for evaluating the effectiveness of measures across different faculties and the inconsistent implementation of best practices, which is often dependent on the initiatives of individual departments or project leaders, such as those involved in the AGRIGEP project.

Focus group discussions were held for three groups: university leadership, middle management with professional services, and students. These discussions aimed to gather detailed information about the implementation of the GEP at three widening Central European universities focusing on agriculture and life sciences (Paksi et al., 2025).

The leadership of the UP demonstrated a clear awareness that transitioning from formal plans to genuine organizational cultural transformation must be grounded in a systematic, long-term strategy that goes beyond mere administrative measures. During the discussions, they particularly emphasized the importance of regularly monitoring concrete indicators, such as the percentage of women in decision-making bodies, the gender ratio in promotions, and employee responses to initiatives for more flexible work arrangements. The leadership noted improvements in committee composition and decision-making, but some inconsistencies remain. These inconsistencies will need to be addressed in the next phase, especially within the framework of the forthcoming GEP 2.0 document.

Middle management and professional services noted that the results of official policies in everyday practice are primarily reflected through departmental work organization, the formation of promotion criteria, and the implementation of mentoring programs for new employees. They pointed out that the training and education carried out in collaboration with the AGRIGEP project contributed to greater awareness of unconscious biases and a more structured introduction of mechanisms to ensure equality. At the same time, disparities among faculties were observed. Some units recognized significant benefits from additional educational activities, while others noted the need for greater administrative and financial support to implement measures uniformly. In this group, it was often emphasized that a university centre or service responsible for gender equality should assume a stronger coordinating role in transferring best practices and collecting data for evaluating effectiveness.

In discussions with students, satisfaction was expressed that the university is increasingly talking about the importance of gender equality, both in the academic context and in society at large. Students reported improved access to information regarding GEP-related activities and praised workshops aimed at educating individuals on how each person can contribute to a more inclusive study environment. Nevertheless, some students pointed out the uneven implementation of measures, as differences among individual faculties or study programs could be quite substantial, indicating the need for a more systematic and coordinated approach. At the same time, several students expressed a desire for even more active involvement in measures that address inequalities, believing that their perspective can contribute to more realistic and long-term effective solutions.

Training sessions and educational workshops intended for all three groups also proved to be an important comple-mentary source of information about current developments and changes occurring in practice. UPC Universitat Politècnica de Catalunya – Barcelona Tech prepared comprehensive training materials on gender in teaching, gender in research, and gender-based violence in the academic environment. An analysis of workshop reports showed that participants, regardless of their function or status, recognized a higher level of awareness of unconscious biases and a heightened sensitivity to fundamental principles of gender equality.

The AGRIGEP project provided significant support by offering appropriate teaching materials and methods for identifying and reducing discriminatory practices. One of the biggest challenges appears to be establishing lasting mechanisms that would continue to encourage sustainability once these trainings have ended, including regular exchanges of experiences and updates of knowledge, especially as new generations of employees or students arrive. One of the opportunities is UP's (2025a) involvement in the Transform4Europe alliance, emphasizing its commitment to innovation and inclusivity. The overall picture that emerged from the document analysis, stakeholder mapping, focus groups, surveys with international students, and training reports indicates that the UP is on the right track to meeting the key goals outlined in its GEP.

Nonetheless, certain structural and organizational issues remain, primarily related to a lack of consistency among faculties, limited administrative resources to support gender equality, and varying degrees of readiness for change. The findings suggest that the preparation and implementation of the revised GEP 2.0 strategy could provide an opportunity to unify standards, strengthen performance monitoring, and continue training all stakeholders, thereby solidifying the foundations for a more balanced and inclusive academic community in the long term.

DISCUSSION

The research results, which combined document analysis, stakeholder mapping, conducting focus groups, administering surveys with international students, and organizing training sessions, indicate that by implementing the GEP, the UP is gradually achieving the core goals of creating a more inclusive academic environment. However, a closer reading of the findings reveals the multifaceted nature of the process and numerous challenges that require attention when upgrading the existing framework within the planned GEP 2.0 document.

Several aspects appear crucial to the long-term success of these initiatives. The first aspect concerns structural and organizational conditions that largely influence the effectiveness of measures such as transparent hiring procedures, the introduction of mentoring systems, and ensuring equal opportunities for promotions. Although the university leadership in the focus groups showed awareness of the importance of gender equality, the results also highlighted the need for a more systematic and uniformly coordinated implementation to prevent practices that remain confined to individual faculties or departments. In this light, strengthening central coordination appears essential, perhaps by establishing or expanding the competencies of an office or committee for gender equality, which would oversee all stakeholders and ensure consistent strategy implementation. Such an approach would, on one hand, support the diversity of local solutions and, on the other, provide minimal standards for the entire institution, aligning with literature recommendations that a unified strategy supported at all levels of governance is crucial for systemic change in higher education institutions (Rosa & Clavero, 2021).

The second aspect concerns the importance of continuous training and education, as participants particularly from middle management and professional services acknowledged that the workshops conducted in collaboration with the AGRIGEP project contributed to greater awareness of unconscious biases and to understanding how these biases affect decision-making processes. Despite the initial successes, it is necessary to emphasize how to ensure the long-term sustainability of such trainings, especially in terms of funding, staffing capacity, and regularly updating the content. Developing competencies and changing institutional culture are processes that require ongoing attention and renewal, as previous studies on introducing innovations in academic environments have also pointed out (Moreira & Sales Oliveira, 2022).

The third aspect highlighted by the results concerns the role of students. In the focus group discussions, students proved receptive and inclined to discuss gender equality, yet they also critically noted the inconsistent implementation of measures across different faculties and programs. These observations indicate that GEP measures may at times be more visible and effective in environments with strong institutional or local initiatives or where highly motivated individuals are involved, while in other areas they remain less prominent. Students therefore expressed a wish for greater involvement and the opportunity to co-create strategies, as they believe their perspectives can help shape solutions more closely aligned with their everyday academic experiences. Involving the younger generation in designing and assessing measures has long been recognized in academic policy development literature as an important factor for enhancing both legitimacy and the sustainable impact of interventions (Correa et al., 2025).

In light of these insights, it appears sensible to take into account, in the design and implementation of the planned new version of the GEP 2.0, the findings that point to the need for more uniform application of measures, strengthened infrastructure (for example, a properly funded office for gender equality), regular training, and ongoing data collection. This would place the university in a better position to monitor relevant indicators, exchange best practices, and respond more rapidly to potential gaps. The research also suggests that partnerships with projects such as AGRIGEP could remain a key source of expert support, both in terms of methodological tools for detecting and measuring unconscious biases and in terms of a community of practice that facilitates the exchange of experiences among various higher education institutions.

Although the example of the UP is specific due to its unique cultural and structural features, the findings presented have broader relevance for any higher education institution seeking to establish or enhance gender equality mechanisms as a factor in creating an inclusive university. Involving all levels of governance, combining various methods of data collection (documentary analysis, focus groups, surveys, workshops), and deliberately investing in ongoing training and awareness-raising for employees and students are widely recognized pillars of an effective process for introducing organizational change. In the future, it would be sensible to extend the measurement of GEP impacts to other areas of the university's activities, for instance the design and content of study programs, while involving further stakeholder groups such as alumni and external partners. Such an approach could provide an even deeper understanding of how gender equality principles manifest in different segments of academic life and which strategies have proven most successful in the long term.

CONCLUSIONS

In recent decades, universities worldwide have increasingly recognized inclusiveness and gender equality as central to institutional integrity, academic excellence, and social responsibility. The UP, as one of Slovenia's youngest and most dynamic universities, offers an important case study in how these values are interpreted, institutionalized, and challenged within the context of higher education in Central and Eastern Europe.

The UP has aligned itself with European and global frameworks promoting equality, including the European Charter for Researchers and the European Commission's requirements for GEPs in research institutions. UP's Strategic Plan emphasizes the creation of an inclusive academic environment, especially through mechanisms ensuring equal opportunities for underrepresented groups, including women, ethnic minorities, and people with disabilities.

In 2021, UP adopted a GEP, which builds on five core pillars: work-life balance, gender balance in leadership and decision-making, gender equality in recruitment and career progression, integration of the gender dimension into research and curricula, and actions against gender-based violence and harassment. These pillars reflect the EU's Horizon Europe policy expectations and place the university in step with broader European efforts to transform academic cultures.

Statistically are provided detailed data on student enrolment, staff composition, and gender distribution at UP. Women represent a significant portion of the student body and academic staff at UP, which mirrors broader national trends in Slovenia (UP, 2025b). At the undergraduate level, women students often outnumber their men counter-parts, particularly in the social sciences (management and tourism), humanities, education, and health sciences. However, disparities become more pronounced in the natural sciences, mathematics, and computer sciences, where women remain underrepresented.

A similar pattern appears in academic career progression. While gender parity is more or less maintained at the entry-level positions (assistants and lecturers), women remain underrepresented in senior academic and leadership positions. This illustrates the structural barriers that can limit women's advancement in academia. The UP has responded by implementing mentorship programs for early-career researchers, leadership training for women, and transparent procedures for hiring and promotion.

One of the innovative elements of UP's approach has been the integration of gender perspectives into curricula and research methodologies. Faculties such as the Faculty of Humanities and the Faculty of Management have introduced gender studies modules and promote research projects that interrogate social structures from an inclusive, intersectional lens. This not only enriches academic inquiry but also fosters critical thinking and social awareness among students.

Interdisciplinary research at the university also reflects a growing sensitivity to gender issues. Projects funded under European frameworks increasingly require the integration of gender as a variable in research design, methodology, and analysis. The Faculty of Health Sciences, for instance, includes gender-based health disparities in public health studies. Such initiatives not only meet funding criteria but contribute meaningfully to knowledge production that serves diverse populations.

Despite policy advances and visible initiatives, challenges persist. Cultural attitudes both within the institution and the wider society can slow the implementation of inclusive policies. Therefore, inclusiveness should go beyond gender to address broader intersectional issues. Students and staff with disabilities, and vulnerable groups individuals may face additional barriers. While UP promotes a policy of non-discrimination, active support systems such as counselling services, accessibility infrastructure, and inclusive language guidelines require continued expansion and funding. The UP has responded with language support programs, international offices, and mentorship schemes, though feedback suggests that more can be done to foster a truly welcoming climate for international students and staff.

Importantly, inclusiveness and gender equality are now framed not just as ethical imperatives but as indicators of institutional excellence. Accrediting bodies and international rankings increasingly factor these into evaluations. For UP, maintaining competitiveness within the European Higher Education Area means sustaining efforts toward a more equitable, transparent, and inclusive academic culture. Among strategic directions can be strengthening gender-disaggregated data collection on regular basis and detailed data analysis that can help identify gaps and monitor progress. In addition, this can encouraging inclusive leadership development programs that actively include women and minority candidates, expand intersectional policies with develop comprehensive inclusion frameworks that address the needs of diverse identities beyond gender, promoting inclusive teaching to train educators in inclusive pedagogies and support diverse learning needs, and foster stakeholders engagement promoting dialogue between the university, the local, national, and international stakeholders to address social inequalities more broadly.

To sum up, the UP exemplifies a proactive and structured approach to inclusiveness and gender equality. The UP demonstrates a strong institutional commitment to inclusiveness and gender equality through strategic planning, targeted initiatives, and international collaboration. Though challenges remain, the UP has laid a strong foundation through its policies, research priorities, and international collaborations. By continuing to address existing challenges and fostering a culture of equity, UP positions itself as a leading example of inclusive excellence in higher education.

ACKNOWLEDGEMENTS

The authors would like to thank the leadership of the University of Primorska, middle management, and the students who participated in the focus groups, the survey of international students, and the training sessions. Special thanks also go to the AGRIGEP project team, whose materials and professional support contributed to the more effective implementation of NES. Finally, we express our gratitude to everyone who contributed to the preparation of documents and shared their experiences for the development of the new Gender Equality Plan GEP 2.0.

REFERENCES

Assessment and implementation of Agriculture and Life Science Universities' first Gender Equality Plans in widening countries. AGRIGEP (2025a). https://cordis.europa.eu/project/id/101094158/results.

AGRIGEP. (2025b). AGRIGEP - Assessment and implementation of Agriculture and Life Science Universities' first Gender Equality Plans in widening countries. https://www.upr.si/en/up-environment/projects-of-the-university-of-primorska/h2020--horizon-europe/agrigep-assessment-and-implementation-of-agriculture-and-life-science-universities-first-gender-equa.

Bojnec, Š. and Blatnik, P. (2024). Vpliv lažnih novic in dezinformacij na prizadevanja za enakost spolov = The impact of fake news and disinformation on gender equality efforts. In: Janko Spreizer, A., Praprotnik, T., Kotnik, L.L.V. (ed.). Enakost, pravičnost in vključevalnost spolov v akademskem okolju=Gender equality, equity and inclusivity in academia: abstracts of the Second Symposium on Gender Equality for an Inclusive University and Society: Koper, 15 November 2024. Koper: University of Primorska Press, 2024. p. 16.

Correa, A., Glas, M.G. and Opara, J. (2025). Females in higher education and leadership: insights from a multi-method approach. Front. Educ. 9:1485395.

Lister, K., Pearson, V. K., Coughlan, T. and Tessarolo, F. (2022). Inclusion in Uncertain Times: Changes in Practices, Perceptions, and Attitudes around Accessibility and Inclusive Practice in Higher Education. Education Sciences 12(8): 571.

Mazancová, J., Bojnec, Š. A and Kobolak, J. (2024a). AGRIGEP: razkrivanje posebnosti kmetijstva in znanosti o življenju pri spodbujanju enakosti spolov = AGRIGEP: uncovering agriculture and life science specificities in advancing gender equality. In: Janko Spreizer, A., Praprotnik, T., Kotnik, L.L.V. (ed.). Enakost, pravičnost in vključevalnost spolov v akademskem okolju=Gender equality, equity and inclusivity in academia: abstracts of the Second Symposium on Gender Equality for an Inclusive University and Society: Koper, 15 November 2024. Koper: University of Primorska Press, 2024. p. 20.

Mazancová, J., Bojnec, Š. and Kobolak, J. (2024b). Vloga kartiranja deležnikov pri spodbujanju enakosti spolov: vpogled z univerz AGRIGEP = Role of stakeholder mapping in advancing gender equality: insights from the AGRIGEP universities. In: Janko Spreizer, A., Praprotnik, T., Kotnik, L.L.V. (ed.). Enakost, pravičnost in vključevalnost spolov v akademskem okolju=Gender equality, equity and inclusivity in academia: abstracts of the Second Symposium on Gender Equality for an Inclusive University and Society: Koper, 15 November 2024. Koper: University of Primorska Press, 2024. p. 11.

Moreira, J.A. and Sales Oliveira, C. (2022). Quantifying for Qualifying: A Framework for Assessing Gender Equality in Higher Education Institutions. Social Sciences 11(10): 478.

Paksi, V., Tardos, K, Takács, J., Suhajda, C., Mazancová, J., Bojnec, Š. and Kobolák, J. (2025). Gender Equality Barriers in Agriculture and Life Sciences in Central European Universities. Social Inclusion 13: 10086.

Rosa, R. and Clavero, S. (2021). Gender equality in higher education and research. Journal of Gender Studies 31(1): 1–7.

University of Primorska (UP, 2025a). Transform4Europe Profile. https://transform4europe.eu/meet-our-universities/university-of-primorska/.

University of Primorska (UP, 2025b). UP in Numbers (2024/2025). https://www.upr.si/en/about-university/up-in-numbers/.

Assessment of the Economic Viability and Environmental Sustainability of Prototypes for Improved Manure Use

Matej Fatur, Luka Juvančič, Rok Mihelič, Ana Schwarzmann and Stane Kavčič

Biotechnical faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia (matej.fatur@bf.uni-lj.si)

ABSTRACT

This study evaluates three innovative manure valorization prototypes Nitrogen Plasma-treated Manure (NPOG), bio-char production via pyrolysis, and microalgae-based biostimulants through a Life Cycle Inventory (LCI), benchmark-ing of cenventional manure and techno-economic analysis (TEA) framework. The NPOG system demonstrated a 40% reduction in ammonia emissions compared to conventional manure spreading but faced economic challenges due to high energy demands (net present value: -€466,582). Biochar production emerged as the most sustainable option, achieving carbon sequestration of -82.8 t CO_2 eq per 40 t biochar and a 44% internal rate of return. Microalgae systems showed marginal feasibility (6% IRR) but enabled nutrient recycling with estimated potential of 5–7% crop yield improvements. While all prototypes reduced reliance on synthetic fertilizers, their scalability hinges on policy interven- tions, particularly subsidies for renewable energy integration and carbon pricing mechanisms. These findings under- score the necessity of balancing technological innovation with economic viability to advance circular economy princi- ples in agricultural waste management.

INTRODUCTION

Livestock manure management remains a critical sustainability challenge, contributing to 14.5% of global anthro-pogenic greenhouse gas emissions through methane release, ammonia volatilization, and nutrient runoff (Adams et al., 2023). Conventional practices, such as direct field application, exacerbate soil acidification and water eutrophi-cation while perpetuating dependence on mineral fertilizers derived from non-renewable resources. Circular bioeconomy strategies offer transformative potential by repurposing waste streams into value-added products, yet their environmental and economic trade-offs require systematic evaluation.

This study investigates three prototypical manure valorization technologies:

I. **Nitrogen Plasma-Treated Manure (NPOG)**: A plasma-assisted process enriching separated manure with atmospheric nitrogen, reducing ammonia emissions by 40% while increasing total nitrogen content from 4 to 6 kg/m^3 (Nyvold & Dörsch, 2023).

II. **Biochar Production**: Pyrolysis of low quality woody biomass at 300–900°C to create a stable carbon amendment, sequestering 9.3 t C/ha/year and enables slower nutrient release and reduces nutrient losses, allowing nutrients to bind more stably in the soil and improving soil water retention by 20% (Lehmann, 2007).

III. **Microalgae Biostimulants**: Nutrient recovery from liquid manure via raceway pond cultivation, achieving 85% nitrogen uptake efficiency and enhancing crop resilience to abiotic stressors (Haider et al., 2022).

The LCI Inventory methodology assessment is based on prototype evaluation. Since we do not have access to actual quantities, the analysis within the LCI was necessarily limited and compared to a benchmark-spreading of manure. Primary inventory data were collected from EcoInvent v3.8 datasets for background processes. Functional units were standardized to 1 t of treated manure for NPOG, 1 t of biochar for pyrolysis, and 1 kg of algal biomass for biostimulants, enabling cross-prototype comparability.

By integrating TEA with LCA, this work addresses a critical gap in circular agriculture research, providing actionable insights for policymakers and stakeholders to prioritize technologies that harmonize environmental benefits with economic feasibility.

MATERIAL AND METHODS

The environmental and economic assessment of the three manure valorization prototypes plasma-treated manure (NPOG), biochar, and microalgae-based biostimulants was conducted using a comprehensive life cycle assessment (LCA) methodology, strictly following ISO 14040:2006 guidelines and best practices from recent LCA literature (Jolliet, et.al.). The methodological approach was structured in several key phases to ensure a robust and comparable evaluation of each prototype. First, a reference scenario was developed for each valorization pathway. This scenario described the prevailing practices for manure and biomass management in Slovenian agriculture, including the collection, storage, processing, and application of raw manure or biomass, as well as the use of mineral fertilizers. The reference scenario served as a baseline for benchmarking the environmental and economic impacts of the innovative prototypes. Second, a detailed life cycle inventory (LCI) was compiled for each prototype. Primary data were collected directly from partnership farms, including precise records of raw material and energy consumption, process yields, direct emissions, and labor requirements. Where primary data were unavailable, secondary data were sourced from scientific literature, technical reports, and the EcoInvent database, ensuring that all relevant flows inputs (raw materials, energy, water), outputs (products, by-products, emissions, waste), and process-specific parameters were systematically captured and quantified. For example, the LCI for the NPOG prototype included all flows related to manure separation, plasma treatment, and storage, while the biochar LCI encompassed woodchip procurement, drying, pyrolysis, and product handling. The microalgae prototype's LCI covered substrate preparation, cultivation, harvesting, and biomass processing.

Third, system boundaries were set according to the "cradle-to-grave" principle, encompassing all life cycle stages from raw material acquisition, through processing and use, to end-of-life or recycling. Special attention was given to the circularity of material flows: in several cases, the end products or by-products of one process were reintroduced as inputs for another, reflecting the circular economy paradigm. This aspect where, instead of final disposal, feedback loops are introduced to return materials to earlier life cycle stages or to new technological processes, thereby closing the loop and reducing waste.

The functional units were carefully defined to enable meaningful comparison between scenarios: one ton of treated manure for NPOG, one ton of biochar for the pyrolysis process, and one kilogram of algal biomass for the microalgae system. All input and output data were normalized to these functional units to facilitate benchmarking and ensure comparability.

The impact assessment phase encompassed the quantification of key environmental indicators, with a primary focus on global warming potential (GWP, expressed as CO_2 equivalents), but also considering nutrient losses, resource use, and other relevant categories where data permitted. Emissions and resource use were calculated for each life cycle stage, and avoided emissions (e.g., from reduced mineral fertilizer use or carbon sequestration in biochar) were subtracted from gross emissions to yield net environmental impacts.

In parallel, a techno-economic analysis was performed. This included a full cost-revenue model for each prototype, accounting for capital expenditures (CAPEX), operational expenditures (OPEX), labor costs, maintenance, and potential revenue streams (e.g., product sales, savings from reduced fertilizer purchases, or carbon credits). The economic performance was assessed using standard indicators such as net present value (NPV), internal rate of return (IRR), and payback period. Sensitivity analyses were conducted to test the influence of key variables such as energy prices, market prices for products, and policy incentives (e.g., subsidies or carbon pricing).

Finally, the results for each prototype were benchmarked against the reference scenario to provide a realistic and context-specific evaluation. This comparative approach allowed for the identification of both environmental and economic trade-offs, as well as the assessment of the scalability and sustainability of each valorization pathway. The methodology also included a discussion of potential system expansion, upcycling, and the integration of circular economy principles, ensuring that the assessment captured the full spectrum of environmental, economic, and social impacts relevant to Slovenian agriculture

RESULTS

The NPOG prototype demonstrated a 40% reduction in ammonia emissions compared to conventional manure application. Plasma treatment increased total nitrogen content in manure from 4 kg/m^3 to 6 kg/m^3 through atmospheric nitrogen fixation, with ammonium nitrate formation lowering pH and stabilizing ammonia. However, the process required 400 MWh/year of electricity to treat 2.000 m3 of manure, resulting in annual greenhouse gas emissions of 89.794 kg CO_2 eq nearly more than double the baseline scenario (38.8 t CO_2 eq). Economic analysis revealed production costs of €39.46/t for single-farm operations and €55.73/t for cooperative systems, exceeding mineral fertilizer prices (€7.81–€21.36/t). The 12-year net present value (NPV) was -€466.582, with breakeven achievable only if electricity prices fell below €0.10/kWh (current: €0.18/kWh). Sensitivity analyses indicated that utilizing excess process heat (60°C water) could reduce energy costs by 15–20%, though this required infrastructure investments.

Biochar production achieved net-negative emissions of -82.8 t CO_2 eq per 40 t output, contrasting sharply with the baseline scenario of woodchip combustion (281.2 t CO_2 eq). The pyrolysis process (300–900°C) converted 160 t of woody biomass into 40 t of biochar annually, sequestering 9.3 t C/ha/year while improving soil water retention (+20%) and pH (0.5–1.0 unit increase). Economically, biochar production costs averaged €1,054/t, but the technology achieved a 44% internal rate of return (IRR).

The microalgae system processed 72 m^3 of separated manure annually into 720 kg of dry biomass, achieving 85% nitrogen uptake efficiency. Raceway ponds (300 m^2) required 2,304 kWh/year for mixing and aeration, generating 268 kg CO_2 eq emissions double the baseline (140 kg CO_2 eq). Biostimulant application improved crop yields by 5–7%. Production costs reached €33/kg biomass, yielding marginal profitability (6% IRR) at a market price of €40/kg for horticultural applications. The 12-year NPV of €1,933 reflected limited scalability, as systems required >300 m^2 pond area for economic viability.

Table 1. Economic analysis and comparative LCA of prototypes for improved manure.

	Total kg CO_2	Net Present Value	Internal Rate of Return	Cost price
NPOG	+ 89.794	-466.582 €	/	39.46 €/t
Biochar	-82.800	+276.282 €	44%	1.054 €/t
Micro Algae	+ 268	+1.933 €	6%	33 €/kg

DISCUSSION

The comparative LCA and economic analysis revealed distinct strengths and limitations for each prototype. The NPOG system offers clear agronomic and environmental advantages by reducing ammonia volatilization and enhancing manure nutrient value, but its high energy demand and resulting emissions outweigh these benefits in the current energy market. The economic analysis further underscores the challenge, as the cost of NPOG-treated manure is not competitive with mineral fertilizers (at the moment), and the investment does not yield a positive return unless electricity prices are substantially reduced or additional value is captured from by-products such as process heat.

Biochar production stands out as the most promising solution, both environmentally and economically. The technology not only sequesters significant amounts of carbon, contributing to climate change mitigation, but also improves soil health and offers a viable business model for farmers. The favorable IRR and positive NPV suggest that biochar could be widely adopted, especially if supported by carbon credit schemes or subsidies for renewable energy use. Nevertheless, market development for biochar and the establishment of quality standards remain important prerequisites for broader deployment (Lehmann, 2007).

The microalgae prototype demonstrates the potential for nutrient recycling and the production of high-value biostimulants, but its scalability is limited by high production costs and relatively modest environmental benefits. The system is best suited for specialized applications or integration into larger circular bioeconomy frameworks where the added value of algal products can be fully realized. Policy support, such as incentives for renewable energy use and the development of certification schemes for biostimulants, could improve the economic outlook for this technology (Haider et al., 2022).

CONCLUSIONS

The assessment of three manure valorization prototypes using LCA apporach and techno-economic analysis highlights the complexity of balancing environmental and economic objectives in the transition to a circular bioeconomy. While NPOG technology delivers clear agronomic benefits, its viability is constrained by high energy consumption and associated costs. Biochar production emerges as the most sustainable and economically attractive option, offering both climate mitigation and improved soil quality. Microalgae-based biostimulants present opportunities for nutrient recycling and value-added products but require further market development and policy support to become broadly feasible. Overall, the successful implementation of these prototypes will depend on integrated strategies that combine technological innovation, supportive policy frameworks, and the active engagement of stakeholders in the agricultural sector

REFERENCES

Nyvold, M. and Dörsch, P. (2023). Plasma-assisted nitrogen enrichment of livestock manure. Frontiers in Sustainable Food Systems 8: 1370542.

Kralj, L. (2024). Separacija gnojevke in uporaba frakcij po separaciji.

EcoInvent Database. (2025). Life cycle inventory data for manure management. https://ecoinvent.org Lehmann, J. (2007). Bio-energy in the black. Frontiers in Ecology and the Environment 5(7): 381–387. Kmetijski inštitut Slovenije. (2025). Modelne kalkulacije mineralnih gnojil.

Haider, M. N., et al. (2022). Nutrient recovery via microalgae cultivation. Fermentation 8(11): 650.

Verification of Economic Feasibility and Environmental Sustainability of Incorporating Unsold Bakery Products into Compound Feed

Matej Fatur, Luka Juvančič, Stane Kavčič and Nejc Šutar

Biotechnical faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia (matej.fatur@bf.uni-lj.si)

ABSTRACT

This paper presents an innovative business model for the production of compound animal feed using unsold bakery products, addressing the dual challenges of food waste reduction and sustainable livestock nutrition. The process involves the collection, depackaging, drying, milling, and enrichment of surplus bread and pastries, transforming them into high-quality feed for cattle, pigs, and poultry. Applying the Triple Layer Business Model Canvas (TLBMC), we assess economic, environmental, and social impacts. Life cycle inventory and cost-benefit analyses indicate that replacing up to 30% of conventional feed ingredients with bakery-derived components can reduce greenhouse gas emissions by nearly 30% CO_2 annually and lower feed costs for farmers. The model supports local supply chains, reduces reliance on imported soy and corn, and creates new opportunities for collaboration between bakeries, feed mills, and farmers. Policy recommendations include the establishment of digital traceability systems and legal frameworks to facilitate surplus food valorization.

INTRODUCTION

Food waste is a significant global issue, with approximately 13% of produced food discarded at the retail and consumer levels, much of it still suitable for consumption (FAO, 2023). Bakery products, due to their short shelf life, constitute a major portion of this waste stream. Conventional disposal methods, such as landfilling or anaerobic digestion, fail to utilize the nutritional value of surplus bread and pastries, while livestock production (in particular hogs, poultry, and cattle) in Slovenia continues to depend heavily on imported feed ingredients like soy and corn. This dependence not only increases production costs but also contributes to harmful displacement effects (eg. stimulating further deforestation and monocultures in South America, emissions from long-distance transport).

To address these challenges, we propose a circular economy solution: the conversion of unsold bakery products into compound animal feed. This business model leverages local resources, reduces food waste, and enhances sustainability in the agricultural sector. The Triple Layer Business Model Canvas (TLBMC) framework, developed by Joyce and Paquin (2016), enables a holistic assessment of economic, environmental, and social dimensions. Our aim is to evaluate the feasibility, benefits, and limitations of integrating bakery waste into animal feed production, and to provide recommendations for stakeholders and policymakers.

MATERIAL AND METHODS

The process of producing animal feed from unsold bakery products is designed as a comprehensive, multi-stage system that maximizes resource efficiency and sustainability. The first stage involves the systematic collection and logistics of surplus bakery items such as bread, pastries, and dough, sourced from bakeries, food processors, and retailers. Establishing reliable partnerships and efficient logistics is essential to ensure that these products are collected promptly, thus preventing spoilage and maintaining the nutritional quality required for animal feed production (FAO, 2023). Direct collaboration with bakeries is preferred, as it enables consistent supply and easier coordination, but cooperation with retailers is also feasible, provided legal requirements for food surplus use are met. Current cost of collection surplus bakery items averages from 0-80€/t.

Upon arrival at the processing facility, bakery products are subjected to depackaging and pre-treatment. Many items are delivered in plastic packaging, which is removed using a specialized depackaging machine with a capacity of 500 kg per hour. For raw dough, thermal treatment (baking) is applied to ensure microbiological safety and product stability. This step is crucial, as it prevents contamination and extends the shelf life of the feed component. The next phase is drying, where products are processed in industrial drying chambers. This controlled drying prevents mold growth and ensures the long-term stability of the feed. The dried products are then milled to a particle size of 2–3 mm using industrial mills, which enhances digestibility for livestock and allows for homogeneous mixing with other feed components.

Mixing and enrichment follow, where the milled bakery fraction is blended with protein sources (such as soybean meal or sunflower meal), minerals, and vitamins. The target inclusion rate for bakery-derived material is 30% of the final feed mix, balancing energy content and digestibility while meeting the nutritional needs of cattle, pigs, or poultry. Industrial mixers ensure even distribution of all ingredients, resulting in a consistent and high-quality compound feed. After mixing, the feed is packaged in bags or stored in bulk, depending on the needs of farms and feed mills. Packaging involves weighing, filling, and sealing, which facilitates transport and storage. The entire process, from collection to packaging, is designed for efficiency and traceability, supporting both food safety and supply chain transparency.

A life cycle inventory (LCI) was established for a model facility processing 500 tons of bakery surplus annually. System boundaries included collection, processing, and distribution. Energy consumption was estimated at 155 kWh per ton of input, totalling 77.500 kWh per year. Environmental impacts were assessed using EcoInvent v3.8 emission factors, focusing on greenhouse gas emissions (CO_2 equivalents). Key environmental benefits include the reduction of methane emissions from landfill avoidance and the substitution of imported soy and corn, which are associated with significant carbon footprints (EcoInvent Database, 2022).

Economic analysis encompassed capital and operational expenditures, including labour costs for two full-time employees, energy, maintenance, and raw material acquisition. Sensitivity analyses considered fluctuations in the price of bakery surplus and energy. The business model was evaluated using the Triple Layer Business Model Canvas (TLBMC), which structures the analysis across economic (value proposition, cost structure, revenue streams, partnerships), environmental (resource efficiency, emission savings, circularity), and social (stakeholder benefits, job creation, supply chain resilience) dimensions (Joyce & Paquin, 2016).

This integrated methodological approach ensures that the production of animal feed from unsold bakery products is assessed not only for technical and economic feasibility but also for its broader environmental and social impacts, supporting the transition to a circular bioeconomy (Osterwalder & Pigneur, 2010; Joyce & Paquin, 2016).

RESULTS

The results of the assessment indicate that substituting up to 30% of conventional feed ingredients with bakery-derived material leads to substantial environmental and economic benefits. For an annual processing volume of 500 tons of bakery products, the total avoided greenhouse gas emissions were estimated at 269.6 tons of CO_2 equivalents per year We estimate that we have reduced the protein requirement from soy by 30%. According to EcoInvent data, the production of 100 tons of soy results in 301 tons of CO_2 emissions. This means our reduction translates to a savings of 270 tons of CO_2, or approximately 29.9%. These savings were achieved through several mechanisms: the diversion of bakery waste from landfill, which reduced methane emissions; the replacement of imported soy and corn, particularly from South America, where 77% of soy-related emissions are attributed to deforestation and logistics; and a reduction in water and land use compared to traditional feed crops (EcoInvent Database, 2022).

The life cycle inventory confirms that the energy requirement for processing is 77.500 kWh per year, or 155 kWh per ton of input. The bakery-based feed successfully replaced 30% of the soy and corn components in compound feed, resulting in a 30% reduction in water use compared to conventional feed production.

From an economic perspective, the total production cost for bakery-based feed ranged from €0.15 to €0.23 per kilogram, depending on the price of raw bakery inputs (assumed between €0 and €80 per ton). This cost is competitive with the average market price of corn (€0.28/kg) from 2018 to 2025 (Agricultural Institute of Slovenia, 2025). The net present value (NPV) of the investment over a 10-year period for the production of 500 tons yearly was calculated at €221.520 and with an internal rate of return (IRR) of 52%. The project supported two full-time jobs and generated annual revenues of €150.000, assuming full capacity utilization.

The business model also fostered collaboration between bakeries, retailers, feed mills, and farmers. Bakeries benefited from reduced disposal costs and enhanced corporate responsibility, while farmers accessed affordable, high-quality feed. The local economy was strengthened through job creation in logistics and processing, and the model contributed to greater food system resilience by reducing reliance on global supply chains and imported feed ingredients. Overall, the results demonstrate that the valorization of bakery surpluses into animal feed is both environmentally and economically sustainable, with significant social benefits for local communities.

DISCUSSION

The findings of this study demonstrate that integrating unsold bakery products into compound animal feed production offers significant environmental, economic, and social advantages. Environmentally, the valorization of 500 tons of bakery surplus per year resulted in a reduction of approximately 270 tons of CO_2 emissions annually, primarily due to the avoidance of landfill methane and the substitution of imported soy and corn, which are associated with high carbon footprints and deforestation, especially in South America (EcoInvent Database, 2022). The process also led to a 30% reduction in water use compared to conventional feed production, further supporting sustainable resource management.

Economically, the production cost for bakery-based feed, ranging from €0.15 to €0.23 per kilogram, proved competitive with the market price of corn, and the calculated net present value and internal rate of return affirm the financial viability of the business model (Agricultural Institute of Slovenia, 2025). This is particularly relevant in the context of rising feed prices and increasing pressure on farmers to reduce input costs. The model also supports job creation, as two full-time positions are required to operate the production line, and it fosters local economic resilience by strengthening supply chains and reducing dependence on global commodity markets.

Socially, the business model encourages collaboration among bakeries, retailers, feed mills, and farmers, leading to reduced food waste, enhanced corporate responsibility, and improved food system resilience. By transforming a waste stream into a valuable resource, the model not only addresses sustainability goals but also contributes to the circular economy and local food security (Joyce & Paquin, 2016). However, the success of such initiatives depends on establishing reliable supply chains, maintaining high standards of food safety and traceability, and ensuring supportive policy frameworks. The implementation of digital platforms for surplus tracking and transparent legal guidelines would further facilitate the scaling of this model.

Compared to traditional animal feed production, the use of bakery surpluses as feed ingredients provides a clear pathway to reducing the environmental footprint of livestock farming, supporting EU Farm-to-Fork and circular economy strategies. Nevertheless, challenges remain, particularly in ensuring consistent supply quality and overcoming logistical barriers. Further research should focus on optimizing nutrient formulations, assessing long-term animal health impacts, and evaluating the scalability of the model in different regional contexts.

CONCLUSIONS

This study confirms that the production of compound animal feed from unsold bakery products is a viable and sustainable strategy for reducing food waste and supporting circular agriculture. The approach delivers measurable environmental benefits, including substantial reductions in greenhouse gas emissions and resource use, while also offering economic gains for feed producers and farmers. Socially, the model strengthens local supply chains and creates employment opportunities, contributing to greater food system resilience. For successful implementation, it is essential to establish efficient collection systems, robust quality control, and supportive policy measures, such as digital traceability platforms and clear regulatory frameworks. Overall, the valorization of bakery surpluses into animal feed represents a replicable and scalable solution for advancing sustainability in the agri-food sector.

REFERENCES

Ecoinvent Database. Ecoinvent Database. https://ecoinvent.org/contact-us/

GreenSpec. Life cycle assessment (LCA). https://www.greenspec.co.uk/life-cycle-assessment-lca/

Joyce, A. and Paquin, R. L. (2016). The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production 135: 1474-1486.

Agricultural Institute of Slovenia. Model calculations.

Osterwalder, A. and Pigneur, Y. (2010). Business model generation: A handbook for visionaries, game changers, and challengers. John Wiley & Sons.

Key Determinants Influencing Income Diversification Among Rural Households in North Macedonia

Marija Gjosheva Kovachevikj[1], Vesna Mrdalj[2], Despina Popovska Stojanov[1] and Lazo Dimitrov[1]

[1] University Ss. Cyril and Methodius in Skopje, Institute of Agriculture - Skopje, Department for Agricultural Business, Economy and Rural Development, Blvd. 16-ta Makedonska brigada, No. 3a, 1000, Skopje, Republic of North Macedonia (m.kovachevikj@zeminst.ukim.edu.mk)

[2] University of Banja Luka, Faculty of Agriculture, Bulevar vojvode Petra Bojovića 1 A, 78000, Banja Luka, Bosnia and Herzegovina

ABSTRACT

Traditional rural development strategies have historically focused on agricultural activities as the primary source of income. However, contemporary approaches increasingly recognize Non-Farm Rural Employment (NFRE) initiatives as essential drivers of economic resilience and livelihood sustainability of rural households. This study examines income diversification among 140 rural households in North Macedonia, using 2018 survey data, categorizing income from agricultural production, non-agricultural rural activities, off-farm employment, transfers and others. The Shannon Index equitability, which captures income diversification through two dimensions: the number and equity of income sources, is employed in this analysis. Using linear regression, the study assesses the influence of specific determinants on diversification index, revealing positive bivariate associations with motivation (r=0.82, p<0.001), agricultural land size (r=0.27, p=0.001), market access (r=0.25, p=0.002), education (r=0.19, p=0.014) and financial access (r=0.21, p=0.006). Multivariate analysis identifies motivation (β=0.75, p<0.001), market access (β=0.16, p<0.001), age (β=0.13, p=0.01) and education (β=0.11, p=0.02) as the sole significant drivers. To effectively diversify rural economies, enhance resilience, and reduce vulnerability, policies should integrate household-level capacity building, such as vocational training, with broader structural interventions, including improved infrastructure and access to financial services. Promoting NFRE through such a dual approach is essential for fostering sustainable rural livelihoods in North Macedonia.

INTRODUCTION

Rural economies around the world are increasingly confronted with challenges arising from climate variability, market volatility and demographic changes. These pressures have prompted a necessary shift away from traditional agrarian livelihoods toward more diversified income strategies. While rural development policies have historically emphasized agricultural intensification as the primary route to poverty alleviation, mounting evidence from sub-Saharan Africa (Barrett et al., 2001), South Asia (Haggblade et al., 2010), and Latin America (Reardon et al., 2001) underscores the growing importance of non-farm rural employment (NFRE) in enhancing income stability, reducing vulnerability and building economic resilience.

Dharmawan and Manig (2000) demonstrate that diversification-based strategies significantly affect rural household welfare, both socioeconomically and environmentally. On the other hand, as urban life becomes unhealthier and more stressful, there is a growing interest among city dwellers in seeking rural services for relaxation, recreation and a healthier lifestyle (Kovachevikj, 2021). Existing research identifies key drivers of diversification, including access to education (Escobal, 2001), financial services (World Bank, 2008), and market linkages (Ellis & Freeman, 2004).

However, in North Macedonia, rural opportunities are significantly shaped by institutional legacies and patterns of uneven development. While agricultural land ownership is frequently associated with a greater capacity for income diversification (Jayne et al., 2003), its relevance and impact within European post-socialist contexts remain insufficiently examined. Likewise, household motivation and cultural attitudes toward non-farm rural employment (NFRE), though potentially decisive, are subjective dimensions that are often overlooked or insufficiently quantified in econometric analyses.

This study addresses two questions: What factors most significantly influence income diversification among rural households in North Macedonia, and how can policymakers leverage these insights to bolster rural resilience? Given the importance of agriculture in North Macedonia, this study asserts that income diversification is influenced by two main factors: (1) household-level characteristics such as land size, education and entrepreneurial motivation and (2) structural conditions like market access and access to finance.

MATERIALS AND METHODS

Sampling and data collection methodology

This study examines rural livelihood strategies through primary data collected from two distinct NUTS-3-level of regions of North Macedonia: Polog and Pelagonia. These regions collectively encompass 28.6% of the country's territory (State Statistical Office, 2022). The analyzed regions were strategically selected to represent the country's socioeconomic and agroecological diversity. In Pelagonia, the sample reflected the region's aging population, Macedonian ethnic majority (86%), and crop-dominated farming systems specializing in tobacco, apples and dairy production (Kovachevikj, 2021). Conversely, the Polog sample represented that region's younger demographics, Albanian ethnic majority (73%), and livestock-based livelihoods centered around pastoral activities (Kovachevikj, 2021). The research employed a stratified random sampling approach to select 140 farm households (70 from each region) from the National Extension Agency registries. The sampling design incorporated critical factors to ensure comprehensive representation, including farm size categories (from smallholdings under 2 hectares to medium farms exceeding 10 hectares), varying levels of access to markets and services, the distinct ethnic compositions characteristic of each region's demographics, and balanced geographic distribution within both Polog and Pelagonia regions.

Trained enumerators conducted in-person interviews using pretested questionnaires that systematically captured: all agricultural and non-agricultural income sources, comprehensive household demographic characteristics, detailed information on asset ownership and productive resources, access to financial services and markets, and perceived constraints and opportunities for livelihood improvement. This multidimensional data collection approach enabled robust analysis of income diversification patterns.

Rural Economic Diversification and Classification of Rural Income Sources

Rural areas are increasingly recognized as spaces of diverse economic activity aimed at supporting the livelihoods of rural populations. These activities include the production of traditional specialty foods, the collection of medicinal, aromatic and ornamental plants, rural tourism, the valorisation of natural assets and traditional landscapes, as well as artisanal crafts and services (Kovachevikj, 2013). This diversification of rural economies reflects a growing shift toward multifunctionality in rural development. The extent and nature of income diversification depend on several interrelated factors: the availability and accessibility of alternative income sources, household capacity to engage in them, and their responsiveness to changing opportunities. These responses are shaped by geographic location, proximity to labour and product markets, access to infrastructure and services, human and social capital, and broader policy environments (ibid).

Rural income can be broadly categorized into several types, reflecting the multifaceted nature of rural livelihoods. Classification used in this research is adapted from Reardon, Berdegué and Escobar (2001) and Ellis (2000), which helps distinguish between different economic activities based on their relationship to farm resources. The main categories include: (1) agricultural income on the farm, (2) non-agricultural rural income on the farm, (3) off-farm income, (4) transfer income and (5) other income. Agricultural Income remains the cornerstone of rural livelihoods. It includes earnings from crop cultivation and livestock rearing. For numerous households, it serves as the primary income base, especially in more remote or farming-oriented communities. Non-Agricultural Rural Income includes activities not directly tied to primary agriculture but still embedded within rural contexts. These include food processing (e.g., cheese-making, grain milling), rural tourism (e.g., agrotourism, homestays, cultural tours), local services (e.g., repair shops, rural transport), artisanal crafts and others. These sectors are vital for promoting rural entrepreneurship, value addition, and economic diversification (Start & Johnson, 2001). Off-Farm Income refers to income from employment beyond the household's agricultural or rural enterprises. Examples include employment in nearby towns or urban centres, seasonal work in construction, or factory jobs. Although often used interchangeably with non-farm income, some scholars differentiate off-farm income as that specifically tied to employment not based on self-enterprise (Ellis, 2000; Barrett et al., 2001). It is particularly significant for households vulnerable to agricultural risks and looking to smooth income flows. Transfer Income includes unearned income from external sources, such as government subsidies, pensions, unemployment benefits and remittances sent by emigrants or diaspora. These transfers provide crucial safety nets and contribute to income stability, especially during agricultural downturns or economic shocks (World Bank, 2008). Other Income encompasses irregular or miscellaneous sources, such as revenue from informal gigs, digital freelancing, or online sales of handmade goods.

Measurement of income diversification

There are several methods to measure the diversification of rural incomes, including the Shannon Index (Wan et al., 2016), the Simpson Index (Koiry et al., 2024) and the Herfindahl-Hirschman Index (HHI) (Banerjee & Mistri, 2019). In this study, the Shannon Index is used as it effectively captures the number of income sources and their proportional distribution. Unlike the Simpson Index and HHI, the Shannon Index is sensitive to variations in smaller income sources and applies logarithmic weighting, preventing dominance bias. Additionally, the Shannon Equitability Index (E), derived from the Shannon Index and commonly used to assess the structural stability of species (Magurran, 1988), is applied to evaluate the equitability of income distribution across households (Wan et al., 2016). The Shannon index for equality is calculated as follows (Schwarze & Zeller, 2005):

$$E = \left[\frac{H_{income}}{-\sum_{i=1}^{S}\left[\left(\frac{I}{S}*\ln\left(\frac{1}{S}\right)\right)\right]}\right]*100$$

$$H_{income} = -\sum_{i=1}^{S}\left[(incshare_i)*\ln(incshare_i)\right]$$

E – Shannon index for equality

S – Number of income sources

$incshare_i$ – The share of income from activity i in the total household income

Ln – Natural logarithm

H_{income} – Shannon index for income diversity within a household, which incorporates the number of income sources and their evenness.

The Shannon index E ranges from 0 to 100 and represents the actual percentage of income diversification relative to the maximum possible income diversification. As the value of the index increases, the degree of income diversification within a household also increases.

Assessing the Influence of Key Determinants on Income Diversification

To assess the influence of key determinants (total income, age structure, education, motivation for RNA, access to finance, agricultural land, clean environment, traditional food and events and market access) on income diversification among rural households, a multiple linear regression model is employed (Wooldridge, 2016). The regression quantifies how these variables collectively explain variations in the Shannon Equitability Index (E), which measures income diversification.

The multiple linear regression model used in this study is specified as follows:

$$E = \beta_0 + \beta_{1x1} + \beta_{2x2} + \ldots + \beta_{kxk} + \varepsilon_i,\ i = 1,\ 2, \ldots, n$$

Where:

E = Shannon Index value for household (dependent variable).

β_0 = intercept

/β_1, β_2, β_3, β_4, ...β_k =regression coefficients for the independent variables (determinants),

x_1, x_2...x_i = explanatory variables

ε_i = error term

In the context of this study, the model is specified as:

$$E = \beta_0 + \beta_1(\text{total income}) + \beta_2(\text{agricultural land}) + \beta_3(\text{age}) + \beta_4(\text{education}) + \beta_5(\text{motivation}) + \beta_6(\text{access to finance}) + \beta_7(\text{market access}) + \beta_8(\text{clean environment}) + \beta_9(\text{tradition}) + \varepsilon_i$$

RESULTS AND DISCUSSIONS

Table 1 provides a comprehensive overview of annual rural income dynamics across five categories. Agricultural income emerges as the dominant source, contributing 53% to total income, with a mean value of 11,794.90 EUR. However, its high variability (coefficient of variation of 80%) underscores significant disparities among households, likely driven by factors such as land ownership, crop yields or market access. Non-agricultural rural activities, while offering a substantial maximum income of 69,430.89 EUR, exhibit extreme variability (coefficient of variation of 230%), reflecting uneven opportunities in sectors like trade, crafts, or services. Despite this potential, the mean income for non-agricultural activities remains low (3,121.94 EUR), indicating that only a minority of households benefit significantly from these ventures. Transfer income (unearned income), which includes remittances, pensions, or welfare payments, serves as a stable and critical component of rural livelihoods. With a coefficient of variation of 72%, it is the least volatile income source and contributes 23% to total income, highlighting its role as a reliable safety net. In contrast, off-farm income (e.g., wage labor) and other income categories are marginal contributors, accounting for 9% and 0.2% of total income, respectively.

Table 1. Descriptive statistics of rural income sources.

Annual rural income categories	Min (EUR)	Max (EUR)	Mean (EUR)	Std. Deviation (EUR)	Coefficient of Variation (%)	Share in Total Income (%)
Agricultural income	-	39,382.11	11,794.90	9,474.26	80.33	52.86
Non-Agricultural rural income	-	69,430.89	3,121.94	7,189.18	230.28	16.12
Off-Farm income	-	10,894.31	1,304.92	2,030.60	155.61	9.32
Transfer income	-	13,034.15	4,082.94	2,940.08	72.01	22.52
Other income	-	2,926.83	47.04	312.23	663.78	0.18
Total income	2,926.83	69,430.89	20,351.73	11,807.45	80.33	100.00

Table 2 presents the descriptive statistics of the variables used in the regression model. The Shannon index, used as the dependent variable, shows moderate variability among the surveyed households, with a coefficient of variation (CV) of 19.75%, indicating a certain level of diversity in income sources across the sample. The average value of the Shannon index is 77.59%, indicating a relatively high level of income diversification among rural households, suggesting that most families rely on multiple income sources, though with moderate variation across the sample. Among the explanatory variables, total annual income averages 20,352 EUR, with a high CV of 80%, suggesting significant economic disparities among rural households. Agricultural land, a key physical asset for economic activity, ranges widely across respondents (0.1 to 45 ha), showing substantial variation (CV = 125.02%), which reflects the unequal distribution of land resources. Age of the household head, who typically serves as the main decision-maker for livelihood strategies, averages 59 years, with relatively low variability (CV = 11.73%), indicating an older population involved in diversification decisions. Education is measured on a scale from 1 to 4 (1 = incomplete primary, 2 = primary, 3 = secondary, 4 = higher/university education), with an average score of 3.01, suggesting that most household heads have completed secondary education. Education, as an important form of human capital, can influence knowledge and skills relevant for non-agricultural activities. Motivation for rural non-agricultural (RNA) entrepreneurship was measured on a scale from 1 (very low) to 5 (very high), averaging 3.26 (CV = 33.63%), pointing to moderate levels of entrepreneurial drive among rural residents. Access to finance, a structural enabler, is included as a binary variable (1 = access, 0 = no access). With a mean of 0.39 and a very high CV (124.76%), the data highlight the unequal availability of financial services, which may constrain diversification opportunities. Market access, also measured as a dummy variable (1 = access, 0 = no access), shows a mean of 0.54 (CV = 92.10%), indicating that slightly more than half of the respondents have some degree of market connectivity. Clean environment is a subjective measure based on residents' perception of environmental quality in their village (1 = clean, 0 = not clean), with a mean of 0.53 and CV of 94.78%. This captures environmental awareness and its potential to support diversification into areas such as eco-tourism or organic agriculture. Finally, traditional food and events are also measured as a binary variable (1 = yes, 0 = no), asking whether respondents believe their village possesses distinct culinary or cultural traditions. A mean of 0.71, suggests that the majority recognize such cultural assets, which can be important for tourism or branding rural products (CV = 64.58%).

Table 2. Descriptive statistics of the determinants used in the regression model.

No	Determinants	Unit	Min	Max	Mean	Std. Deviation	Coefficient of Variance (%)
1	Shannon index	%	34.00	100.00	77.59	15.33	19.75
2	Total income	euros	2,926.83	69,430.89	20,351.73	11,807.45	80.33
3	Agricultural land	ha	0.10	45.00	4.61	5.76	125.02
4	Age of the household head	years	25.00	70.00	59.07	6.93	11.73
5	Education degree	degree*	1.00	4.00	3.01	0.50	16.69
6	Motivation for RNA	metric	1.00	5.00	3.26	1.10	33.63
7	Access to finance	dummy	0	1	0.39	0.49	124.76
8	Market access	dummy	0	1	0.54	0.50	92.10
9	Clean environment	dummy	0	1	0.53	0.50	94.78
10	Traditional food and events	dummy	0	1	0.71	0.46	64.58

*1=incomplete primary education, 2=primary education, 3=secondary education, 4=higher and university education

The results of the Pearson correlation between the Shannon index and each independent variable are displayed in Table 3. Motivation for RNA ($r = 0.82$, $p<0.05$), agricultural land ($r = 0.27$, $p<0.05$), market access ($r = 0.25$, $p<0.05$), age ($r = 0.24$, $p<0.05$) and access to finance ($r = 0.212$, $p<0.05$) are positively and significantly correlated with the Shannon index, indicating their notable role in shaping income diversification patterns among rural households. In contrast, total income and clean environment do not indicate statistically significant correlations with the Shannon index. The low influence of income may reflect the current underdevelopment of rural non-agricultural activities (RNA) in North Macedonia, where income sources remain limited and concentrated in traditional sectors, such as agriculture. Regarding the clean environment, the lack of correlation might stem from insufficient awareness among rural residents that environmental quality is a fundamental condition for the development of sustainable rural economies, such as eco-tourism or organic production.

Table 3. Pearson correlation coefficients between determinants and the Shannon index of income diversification.

Variable	Pearson Correlation	Sig. (1-tailed)
Total income	0.04	0.321
Agricultural land	0.27	0.001***
Age	0.24	0.002**
Education	0.19	0.014*
Motivation	0.82	0.001***
Access to finance	0.21	0.006**
Market access	0.25	0.002**
Clean environment	–0.02	0.422
Tradition	0.18	0.019*

* ($p < 0.05$), ** ($p < 0.01$), *** ($p < 0.001$)

Table 4 displays the model summary of the multiple linear regression. The model explains 73.4% of the variance in the Shannon index ($R^2 = 0.734$), with a good overall model fit (Adjusted $R^2 = 0.716$; $F(9,130) = 39.87$, $p < 0.001$). The Durbin-Watson statistic is 2.047, indicating no autocorrelation in the residuals.

Table 4. Model summary of the multiple linear regression model.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
				R Square Change	F Change	df1	df2	Sig. F Change	
0.857a	0.734	0.716	0.08173	0.734	39.866	9	130	0.000	2.047

Table 5 reports the coefficients of the regression model. Motivation for RNA ($\beta = 0.751$, $p < 0.001$), market access ($\beta = 0.162$, $p = 0.001$), age ($\beta = 0.133$, $p = 0.006$), and education ($\beta = 0.113$, $p = 0.018$) have significant positive effects on the Shannon index. Other variables, such as income, access to finance, agricultural land, clean environment, and traditional food and events, do not show statistically significant effects. VIF values are all below 1.2, indicating no multicollinearity issues.

Table 5. Coefficients of multiple linear regression model (Dependent variable: Shannon index).

Variable	B (Unstandardized)	Std. Error	Beta (Standardized)	t	Sig.	VIF
(Constant)	0.11	0.08	–	1.43	0.16	–
Total Income	–5.567E-7	-	–0.043	–0.919	0.36	1.07
Agricultural Land	0.00	0.00	0.03	0.62	0.54	1.15
Age	0.00	0.00	0.13	2.79	0.01**	1.11
Education	0.04	0.01	0.11	2.40	0.02*	1.09
Motivation For RNA	0.11	0.01	0.75	15.18	0.000***	1.20
Access To Finance	0.01	0.02	0.04	0.78	0.44	1.14
Market Access	0.05	0.01	0.16	3.51	0.00***	1.04
Clean Environment	0.00	0.02	0.00	0.07	0.94	1.11
Tradition	0.03	0.02	0.08	1.62	0.11	1.04

* ($p < 0.05$), ** ($p < 0.01$), *** ($p < 0.001$)

CONCLUSIONS

The findings on the structure of rural income sources underscore the dual challenges facing rural economies: a predominant dependence on agriculture, often unstable due to climate variability and market risks, and unequal access to rural non-agricultural (RNA) opportunities. Although agriculture remains the backbone of rural livelihoods, its volatility exposes households to considerable vulnerability. Non-agricultural activities, while holding strong potential for diversification, remain underutilized due to barriers such as limited access to finance, lack of skills, or inadequate infrastructure. The relatively stable share of transfer income further highlights the critical role of social protection mechanisms in cushioning rural poverty.

The statistical results highlight the complexity of rural income diversification. Motivation emerges as the strongest driver, supported by market access, age and education. These findings emphasize the combined role of personal initiative and supportive conditions, while factors like income, land, finance and environmental or cultural aspects show limited direct influence.

Successful diversification strategies in rural areas rely less on economic resources alone and more on personal readiness, accessible markets and educational background. For policymakers, this underlines the need to go beyond financial support and address the broader social and institutional conditions that empower rural households to engage in non-agricultural activities and reduce their vulnerability. Additionally, the limited influence of environmental factors points to the need for greater awareness among rural populations about the potential of environmental quality for economic diversification. In terms of access to finance, although a strong influence was initially expected, the results showed otherwise. This may indicate that financial support alone is not sufficient to drive diversification. Rather, it probably needs to be complemented by additional measures such as training, advisory services and targeted investment programs to effectively empower rural households to engage in non-agricultural activities. Future research could include a more detailed classification of income sources to better capture their impact.

REFERENCES

Banerjee, R. and Mistri, B. (2019). Impact of coal mining in diversification of rural livelihoods: A case study in the Barjora Colliery Area of Bankura District, West Bengal. Space and Culture, India 6(5): 228–240.

Barrett, C. B., Reardon, T. and Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics, and policy implications. Food Policy 26(4): 315–331.

Dharmawan, A. H. and Manig, W. (2000). Livelihood strategies and rural changes in Indonesia: Studies on small farm communities. In: Proceedings of the International Agricultural Research Conference, University of Hohenheim (Session: Assessment of Poverty and Livelihood Strategies, pp. 1–9).

Ellis, F. (2000). Rural livelihood and diversity in developing countries. Oxford University Press.

Ellis, F. and Freeman, H. A. (2004). Rural livelihoods and poverty reduction strategies in four African countries. Journal of Development Studies 40(4): 1–30.

Escobal, J. (2001). The determinants of nonfarm income diversification in rural Peru. World Development 29(3): 497–508.

Haggblade, S., Hazell, P. and Reardon, T. (Eds.). (2010). The rural non-farm economy: Prospects for growth and poverty reduction. International Food Policy Research Institute (IFPRI).

Jayne, T. S., Yamano, T., Weber, M. T., Tschirley, D., Benfica, R., Chapoto, A., & Zulu, B. (2003). Smallholder income and land distribution in Africa: Implications for poverty reduction strategies. Food Policy 28(3): 253–275.

Koiry, S., Kairi, B. and Pooja, P. (2024). Impact of income diversification on multidimensional poverty: Household level evidence from tea estates in Bangladesh. Heliyon 10(5).

Kovachevikj, Gj. M. (2013). Rural economy. Federation of Farmers of the Republic of Macedonia.

Kovachevikj, Gj. M. (2021). Resource management and their socio-economic impact on rural households in the Republic of Macedonia – Case study in Polog and Pelagonia Region in the Republic of Macedonia. Institute for Sociological, Political and Juridical Research (ISPPI), University Ss. Cyril and Methodius in Skopje.

Magurran, A. E. (1988). Ecological diversity and its measurement. Princeton University Press.

Reardon, T., Berdegué, J. A. and Escobar, G. (2001). Rural nonfarm employment and incomes in Latin America: Overview and policy implications. World Development 29(3): 395–409.

Schwarze, S. and Zeller, M. (2005). Income diversification of rural households in Central Sulawesi, Indonesia. Quarterly Journal of International Agriculture 44(1): 61–73.

Start, D. and Johnson, C. (2001). Transformation, well-being, and the state: Rural livelihoods diversification in South Asia. Overseas Development Institute.

State Statistical Office. (2022). Regions in the Republic of North Macedonia 2022, Regional yearbook: SSO. Skopje, North Macedonia.

Wan, J., Li, R., Wang, W., Liu, Z. and Chen, B. (2016). Income diversification: A strategy for rural region risk management. Sustainability 8(10): 1–15.

Wooldridge, J. M. (2016). Introductory econometrics: A modern approach (6th ed.). Cengage Learning.

World Bank. (2008). World Development Report 2008: Agriculture for development. World Bank Publications.

Does Complexity Pay Off? An Evaluation of Choice Models on Black Slavonian Pig Meat

Sanja Jelić Milković[1], Ružica Lončarić[1], Igor Kralik[1], Jelena Kristić[1], Ana Crnčan[1], Lucija Pečurlić[1] and Maurizio Canavari[2†]

[1] Josip Juraj Strossmayer University in Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia (sanja.jelic@fazos.hr)

[2] Alma Mater Studiorum University of Bologna, Department of Agricultural and Food Sciences, Viale Fanin 50, 40126 Bologna, Italy

ABSTRACT

This study compares the predictive and explanatory power of different discrete choice models applied to consumer preferences for fresh pork from the Black Slavonian Pig breed. Using data from a labelled discrete choice experiment (DCE), we estimate and evaluate the performance of four models: the multinomial logit (MNL), random parameters logit (RPL) and the RPL with error components (RPL-EC) without and with interaction. The results are evaluated using statistics on model fit, parameter significance and the ability to capture preference heterogeneity. The results contribute to methodological insights for applied choice modelling and practical implications for marketing strategies in the agri-food industry.

INTRODUCTION

Aizaki (2012) explains that the choice experiment (CE), also called a discrete choice experiment (DCE), is a well-established method that was first used by Louviere and Hensher (1982) and Louvière and Woodworth (1983). Since then, it has grown into a widely used research tool in fields like market research, economics, agricultural economics, transport and health. DCEs are popular because they can answer important research questions that other methods often cannot. For example, they help researchers understand consumer preferences, measure the trade-offs people are willing to make between different product features, and estimate both financial and non-financial values (Lancsar et al., 2017; Fiebig et al., 2010). In recent years, understanding consumer preferences for food characteristics has become essential for the development of targeted marketing strategies, especially for traditional and local foods. In this context, fresh meat from indigenous breeds such as the Black Slavonian Pig has attracted great interest due to its special quality characteristics and cultural value. In this study, a labelled (alternative-specific) DCE also known as a stated choice (SC) experiment was used to study consumer preferences for fresh pork from the Black Slavonian Pig. Discrete choice experiments (DCE) have proven to be a powerful tool for assessing how consumers trade off different product attributes when making purchasing decisions. The main objective of this study is to examine both the theoretical foundations and empirical applications of models used in discrete choice experiments, and to evaluate and compare the performance of several discrete choice models in explaining consumer preferences for Black Slavonian Pig meat. The paper investigates whether more advanced models such as the random parameter logit (RPL) and the error component random parameter logit (RPL-EC offer improved model fit and richer behavioural insights compared to the standard multinomial logit (MNL) model.

In today's modern and postmodern societies, food choice has become a complex process, requiring consumers to assess multiple product characteristics before making a buying decision (Nocella et al., 2012). According to the authors, attributes such as price and sensory qualities (organoleptic features) are relatively easy to evaluate in choice experiments. However, credence attributes those not directly observable or verifiable by the consumer, such as ethical production or nutritional value are more difficult to assess, which complicates the modelling of preferences related to these features. Discrete choice experiments (DCE) are grounded in Lancaster's theory of utility maximization (Lancaster, 1966), which argues that utility is not derived from the product itself, but from its individual attributes. Thus, a product's overall utility is considered to be the sum of the utilities of its individual attributes and their levels. In a typical DCE, participants are presented with several mutually exclusive alternatives, each defined by different combinations of attributes, and are asked to select the one they prefer most. They are not required to state how much they prefer one option over another or how much they value specific attribute changes; rather, they simply choose their preferred alternative (James and Burton, 2003). The methodological foundation for this approach lies in McFadden's random utility theory (Louviere et al., 2000; Bateman et al., 2004; Train, 2009; De-Magistris and Gracia, 2016; Mariel et al., 2021), which is based on the principle of utility maximization. According to this theory, if a person selects one option over another, it implies that the chosen option provides higher utility (Vojáček and Pecáková, 2010). Researchers then use the attributes of the chosen and unchosen alternatives to infer preferences and estimate welfare measures consistent with microeconomic theory (Hu et al., 2022). Discrete choice models are based on the idea of indirect utility and are usually analysed using the random utility maximization (RUM) framework, which assumes people choose what gives them the most benefit (Mariel et al., 2021). RUM was first developed by Thurstone (1927) and later expanded by McFadden (Train, 2009). In this framework, each person chooses from several alternatives over one or more choice occasions. The utility (or satisfaction) that a person gets from an option is made up of two parts: one part is based on things we can observe (like price or product quality), and the other is random or unobserved. We write this as:

$$U_{njt} = V_{njt} + \varepsilon_{njt}$$

Here, V_{njt} is the observed (deterministic) part, and ε_{njt} is the unobserved (random) part of utility (Train, 2009; Mariel et al., 2021). RUM is used when people choose from a fixed number of options. The utility a person gets from an alternative can be expressed as:

$$U_{nj} = V_{nj}\left(x_{nj}|\beta_j\right) + \varepsilon_{nj}$$

In this case, x_{nj} is a set of attribute levels (like price or origin), and β_j are the weights or importance placed on these attributes (Bliemer et al., 2005). When the experiment uses alternative-specific attributes, separate parameters are estimated for each one. In contrast, in a generic experiment, a single parameter is used for each attribute across all alternatives. These are shown in the following formulas:

$$V_{nj}(x_{nj}|\beta_j) = \sum_{k=1}^{K_j} x_{njk}\beta_{jk},$$ alternative specific attributes

$$V_{nj}(x_{nj}|\beta) = \sum_{k=1}^{K} x_{njk}\beta_{k},$$ generic attributes

According to Train (2009) and Louviere et al. (2010), people choose the option with the highest utility. So, the probability that someone chooses option i is:

$$P(i|C_n) = P[(V_{ni} + \varepsilon_{ni}) > \text{Max}\,(V_{nj} + \varepsilon_{nj})],$$ for all *j* options in the choice set C_n

Because of the random component ε_{nj}, we can't know exactly what a person will choose, but we can estimate the probability of each option being chosen (Louviere et al., 2010). These probabilities are calculated using specific statistical models that are made for analysing choice behaviour. In this study, four such models were used, each allowing for different levels of preference variation and model complexity. The multinomial logit model (MNL) is the simplest specification within the RUM framework. It assumes homogeneity in preferences and independence of irrelevant alternatives (IIA), which may not reflect decision making in reality. To address these limitations, the random parameter logit model (RPL) introduces preference heterogeneity by allowing the coefficients to vary randomly between individuals. The RPL model with error components (RPL-EC) extends the RPL model by including additional error terms that capture the correlation between the alternatives. Each of these models serves as a different lens through which to view consumer decision-making. A comparison of these models helps to evaluate the trade-offs between model simplicity, flexibility and explanatory power.

MATERIALS AND METHODS

The dataset was collected through an alternative-specific (labelled) hypothetical discrete choice experiment (DCE) designed to assess consumer preferences and willingness to pay (WTP) for fresh meat of the Black Slavonian Pig. To construct the choice tasks, a D-efficient experimental design was used, generated using the Ngene version 1.2.1. The design was optimized for statistical efficiency based on the multinomial logit model, ensuring balanced representation of attribute levels across choice tasks. Each respondent was presented with 12 choice sets, each containing two labelled alternatives. Attribute combinations were generated under plausibility constraints, ensuring that only realistic and interpretable product profiles were included. The design allowed estimation of main effects and interactions with the information treatment. The labelled alternatives represented two production systems outdoor and semi-indoor while each alternative varied across three attributes: meat colour (dark or light red), geographical origin (Continental Croatia, Continental Croatia + PDO, and other regions), and price (70.00, 120.00, and 170.00 HRK/kg). The utility function guiding the design was:

U = f {Price, Colour, Geographical information, ε}

Participants were randomly assigned to either a control or information treatment group. The information treatment provided additional context about the production systems, animal welfare, environmental impacts, and the meaning of the product attributes. This design enabled the evaluation of how additional product information influences consumer choice and captures the role of social concerns in food preferences. A total of 410 respondents completed 12 choice tasks each, generating 4,920 observations. The choice data were analyzed using four models of increasing complexity: the multinomial logit (MNL), random parameter logit (RPL), and error component random parameter logit (RPL-EC without and with interaction) models. These were estimated using the mlogit (Croissant, 2020), gmnl (Sarrias and Daziano, 2017), and lmtest (Zeileis and Hothorn, 2002) packages in R (version 4.0.2). All models considered a panel structure. In the RPL and RPL-EC models, all main effect variables except price were specified as random parameters with normally distributed coefficients. Simulations were conducted using 1,000 Halton draws for the RPL and RPL-EC model and 100 Halton draws for the RPL-EC model with treatment (interaction). Explanatory variables were grouped into main effects and information treatment indicators; all non-price variables were effect coded.

RESULTS AND DISCUSSION

The multinomial logit (MNL) model, a well-known member of the random utility maximization (RUM) family, is primarily valued for its simplicity in both estimation procedures and the interpretation of choice probabilities and elasticities (Sarrias and Daziano, 2017). However, one major limitation of the MNL model is its inability to accommodate individual-specific preferences, as it enforces uniform substitution patterns across alternatives due to the independence of irrelevant alternatives (IIA) assumption (Sarrias and Daziano, 2017). As Hensher et al. (2005) explain, this means that the ratio of the probabilities of choosing between any two options remains unchanged, regardless of the inclusion or exclusion of other options in the choice set. The MNL model assumes that all unobserved components of utility (ε_{njt}) are independently and identically distributed (IID) across alternatives (Twaddle, 2011; Wongprawmas, 2013). Under this assumption, the probability that consumer i selects alternative j is expressed as:

$$P_i = \frac{\exp(V_i)}{\sum_{j=1}^{J} \exp(V_j)}$$

The IID assumption requires that the error terms for each alternative have the same statistical distribution, are uncorrelated with one another, and have separate mean values (Jaeger and Rose, 2008). However, this assumption is often unrealistic in practical applications, where choice behavior commonly violates these conditions. Labelled choice experiments, in particular, frequently breach the IID assumption, as participants may use the labels of alternatives to infer unobserved information. These inferences are typically correlated with the unobserved component of utility, undermining the IID requirement (Jaeger and Rose, 2008). Additionally, McFadden (1973) notes that the MNL model assumes that all consumers share identical preferences and respond similarly to observed attributes. Yet, as Wang et al. (2018) point out, this homogeneity assumption often does not hold in reality, necessitating the use of more flexible models that can account for variations in individual preferences. A key limitation of the Multinomial Logit (MNL) model is its assumption of uniform preferences across all individuals. To address this, several extensions have been developed to allow for more flexible assumptions. One such extension is the Mixed Logit (MXL) model also known as the Random Parameter Logit (RPL) model which assumes that individual preferences vary randomly around the population mean of each parameter. The application of the MXL model involves three main specification decisions: identifying which parameters should be treated as random, selecting an appropriate distribution for those parameters, and interpreting the economic meaning of the random coefficients (Hoyos, 2010). Hoyos (2010) suggests that the standard way to determine which parameters to model as random is to compare model specifications using the Likelihood Ratio (LR) test. The mixing distribution can be either discrete or continuous; when continuous, it allows the MXL framework to be used to derive a RPL or an error component model. Another issue arises when a status quo alternative is present, as preference variability may differ for this option compared to others. In such cases, the Error Component Random Parameter Logit model (RPL-EC) is appropriate, as it accounts for both general preference heterogeneity and the unique treatment of the status quo alternative. Unlike the MNL model, where preference parameters are fixed, the MXL framework allows these parameters to vary across choices, individuals, or both, and fully relaxes the independence of irrelevant alternatives (IIA) assumption (Christiadi and Cushing, 2007; Mariel et al., 2021). The utility function in this model is expressed as:

$$U_{nj} = \beta_n' X_{nj} + \varepsilon_{nj}$$

Here, X_{nj} represents observed attributes of the alternatives, and β_n is a vector of individual-specific taste parameters, allowing preferences to vary across respondents. Similar to the MNL model, the error term ε_{nj} is assumed to be independently and identically distributed with an extreme value distribution (Christiadi and Cushing, 2007; Train, 2009). The main advantage of the MXL model lies in its flexibility: it allows for differences in how individuals value product attributes by permitting the coefficients β to vary across people. This makes the model particularly suitable for capturing the realworld diversity of consumer preferences (Christiadi and Cushing, 2007; Train, 2009). Because the multinomial logit (MNL) model assumes uniform preferences across all consumers, this paper instead employs the random parameter logit (RPL) model and the error component random parameter logit (RPL-EC) models, both of which relax this assumption and allow for individual level variation in preferences. In these models, random coefficients capture the diversity of preferences across the sample. While the random parameters reflect variability in taste among individuals, the error components help account for correlation patterns between utilities of different alternatives by decomposing the error term (Scarpa et al., 2005; Train, 2009; Marsh et al., 2011). In the RPL framework, choice probabilities are calculated by integrating standard logit probabilities over the full range of possible values of the random parameters. The probability that individual n chooses alternative i is given by:

$$P_{ni} = \int \left(\frac{e^{\beta' X_{ni}}}{\sum_j e^{\beta' X_{ni}}} \right) f(\beta) d\beta$$

This formulation shows that the RPL probability is a weighted average of the logit probabilities, where the weights are defined by the probability density function $f(\beta)$. Since this expression involves a multi-dimensional integral without a closed form solution, it is typically evaluated through simulation methods (Christiadi and Cushing, 2007; Train, 2009; Wang et al., 2018). A key strength of the RPL model lies in its ability to link each attribute's mean effect with the degree of individual-specific variation in that effect. As Vojáček and Pecáková (2010) note, for each attribute, the combination of its mean estimate, the associated heterogeneity, and the standard deviation of its parameter provides insight into the utility that an individual derives from a given alternative. The mixed logit (MXL) model can be specified without relying solely on the interpretation of random coefficients; instead, it may represent error components that introduce correlations between the utilities of different alternatives. Regardless of whether the model uses random parameters or error components, the chosen mixing distribution captures the variance and correlations arising from unobserved factors (Train, 2009). In the RPL-EC model, utility is expressed as:

$$U_{nj} = \alpha' X_{nj} + \mu'_{n} Z_{nj} + \varepsilon_{nj}$$

Here, X_{nj} and Z_{nj} are vectors of observable attributes for alternative j, α represents fixed coefficients, μ is a vector of random terms with a mean of zero, and ε_{nj} is an independently and identically distributed extreme value error term. The elements in Z_{nj} serve as error components, which together with ε_{nj} form the unobserved part of utility (Train, 2009). These error components capture correlations among alternatives by introducing shared random terms between alternatives that are perceived as close substitutes or unique to particular options (Scarpa et al., 2005; Mørkbak et al., 2010). They are assumed to follow a normal distribution with zero mean and a standard deviation σμi, where the estimated standard deviation reflects either the correlation between alternatives or variation specific to individual options (Mørkbak et al., 2010). When each alternative has its own unique error component, the model becomes heteroscedastic, and when alternatives share subsets of the error components, the model structure can resemble a nested system (Scarpa et al., 2005; Mørkbak et al., 2010). Beyond identifying heterogeneity around mean estimates through standard deviation, the MXL model can also reveal the sources of heterogeneity through interaction between random parameters and other variables (Rasciute and Pentecost, 2008). As noted by Rasciute and Pentecost (2008) and Green (2010), interaction effects in non-linear models depend not only on the coefficients for the interaction terms but also on the main effects and the values of the interacting variables. In this study, explanatory variables were grouped into two categories: main effects of product attributes and interaction terms. According to Kjær (2005), including interaction terms in the utility function can be highly valuable. These terms can represent interaction between two attributes (e.g., X1 * X2) or between an attribute and a personal characteristic (e.g., S1 * X2, where S is a vector of interaction term variables - information treatment). By modelling these interaction, choice experiments allow researchers to explore how different product attributes relate to one another even though respondents are not explicitly asked to rank the importance of each attribute (Ortega et al., 2016). Additionally, Kjær (2005) emphasizes that including interaction term variables in the model enables researchers to capture individual level preference heterogeneity and conduct subgroup analyses, providing deeper insights into consumer behaviour. Based on the theoretical framework presented above, Table 1. summarizes the statistical performance of each estimated discrete choice model applied to consumer preferences for Black Slavonian Pig meat. The table reports the log-likelihood values, along with the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), which are standard measures for comparing model fit. Lower AIC and BIC values indicate better model performance, as they account for both goodness of fit and model complexity.

Table 1. Model fit corporatisation.

Model	Log-Likelihood	AIC	BIC
MNL	-5096.4	10214.8	10286.4
RPL	-4915.7	9865.4	9975.9
RPL-EC	-3272.1	6580.1	6697.2
RPL-EC (with interaction)	-3273.1	6588.3	6724.8

MNL – multinomial logit, RPL – random parameter logit, RPL-EC – error component random parameter logit, RPL-EC (with interaction) – error component random parameter logit with interaction, LCM – latent class model, LR test – log likelihood ratio test, AIC – Akaike information criteria, BIC – Bayesian information criteria.

Each discrete choice model estimated in this study possesses specific properties that define its structure, behavior, and statistical performance. The foundational property of each model lies in its type: the multinomial logit (MNL) model assumes fixed coefficients and relies on the independence of irrelevant alternatives (IIA), while the random parameters logit (RPL) model introduces random taste variation to capture unobserved heterogeneity. The RPL with error component (RPL-EC) models further extends this by allowing for correlation in unobserved utility components through additional error terms. Model properties also include quantitative fit statistics such as log-likelihood, AIC and BIC which are used to evaluate and compare model performance. Estimation related features, such as the use of panel data, the number of simulated draws for RPL models, and optimization methods (e.g., BFGS), also contribute to a model's overall specification. Behavioural assumptions such as the presence or absence of IIA, the ability to model status quo bias (e.g., via the non-status quo variable), and the way preference heterogeneity is handled are central to interpreting model outputs. Finally, model properties include the estimated parameters themselves: mean coefficients, standard deviations of random effects and interaction terms (information treatment). Together, these properties determine each model's ability to capture and explain consumer decision making in the context of fresh pork preferences. The results of this study presented in the Table 1. demonstrate a clear improvement in model performance as complexity increases. The multinomial logit model (MNL) model, while straightforward, assumes homogeneous preferences and fails to capture unobserved heterogeneity, yielding the lowest model fit with an AIC of 10214.8. The random parameters logit (RPL) model improves upon this by allowing for individual level variation in preferences, with significant random parameters indicating meaningful heterogeneity and a reduced AIC of 9865.4. The best fitting model overall is the RPL with error component (RPL-EC), which not only incorporates random taste variation but also accounts for correlation across unobserved factors and preference for the status quo, as captured by the significant non-status quo parameter. This model achieves the lowest AIC (6580.1) and BIC (6697.2), and its superior performance is confirmed by likelihood ratio tests comparing it to both the MNL and RPL models ($p < 0.001$). Although a variant of the RPL-EC model including treatment (interaction) level was tested, it did not significantly improve model fit ($p = 0.549$) but RPL-EC model with interaction terms can still be valuable for gaining additional behavioural insight to uncover how treatment variables influence preferences. In conclusion, the RPL-EC with interaction terms model strikes the best balance between flexibility, behavioural realism, and statistical efficiency, making it the most appropriate model for capturing consumer preferences for Black Slavonian Pig meat in this discrete choice experiment.

CONCLUSIONS

This study compared the performance of several discrete choice models in capturing consumer preferences and willingness to pay (WTP) for fresh meat from the Black Slavonian Pig. The results clearly demonstrate that increasing model complexity leads to better model fit and deeper behavioral insight. While the MNL model provided a useful baseline, it was limited by its assumptions of homogeneous preferences and independence of irrelevant alternatives (IIA). The RPL model improved upon this by allowing for individual-level preference heterogeneity, and RPL-EC model offered the best overall performance by also accounting for correlation across alternatives and status quo effects. Thus, the RPL-EC model, with or without interaction, is the most appropriate model for analyzing consumer preferences in this context, providing robust and nuanced understanding of the market for traditional meat products.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the late Prof. Maurizio Canavari (Department of Agricultural and Food Sciences, University of Bologna) for his invaluable guidance in designing the discrete choice experiment. This work is submitted in his memory with deep appreciation for his mentorship and contributions.

REFERENCES

Aizaki, H. (2012). Choice Experiment Applications in Food, Agriculture, and Rural Planning Research in Japan. Agri-Bioscience Monographs 2(1): 1–46.

Bateman, I.J., Carson, R.T., Day, B., Dupont, D., Louviere, J.J., Morimoto, S., Scarpa, R. and Wang, P. (2004). Choice Set Awareness and Ordering Effects in Discrete Choice Experiments. CSERGE Working Paper EDM 08-0.

Bliemer, M.C.J. and Rose, J.M. (2005). Efficient Designs for Alternative Specific Choice Experiment. Working paper IKTLS-WP-05-04, Institute of Transport and Logistics Studies, Australia, 1–20.

Cushing, B. J. (2007). Conditional Logit, IIA, and Alternatives for Estimating Models of Interstate Migration. Regional Research Institute Working Papers 65: 1–28.

Croissant, Y. (2020). Estimation of Random Utility Models in R: The mlogit Package. Journal of Statistical Software 95(11): 1–41.

De-Magistris, T. and Gracia, A. (2016). Do consumers care about organic and distance labels? An empirical analysis in Spain. International Journal of Consumer Studies 38: 660–669.

Fiebig, D. G., Keane, M. P., Louviere, J. and Wasi, N. (2010). The Generalised Multinomial Logit Model: Accounting for Scale and Coefficient Heterogeneity. Marketing Science 29(3): 393–421.

Greene WH. (2010). Testing Hypotheses about Interaction Terms in non-Linear Models. Economic Letters 107(2): 291–6.

Hensher, D.A., Rose, J. M. and Greene, W. H. (2005). Applied Choice Analysis: A Primer. Cambridge University Press, Cambridge.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. Ecological Economics 69: 1595–1603.

Hu, W., Sun, S., Penn, J. and Qing, P. (2022). Dummy and effects coding variables in discrete choice analysis. Agricultural & Applied Economics Association 104(5): 1–19.

Jaeger, S.R. and Rose, J.M., (2008). Stated choice experimentation, contextual influences, and food choice: A case study. Food Quality and Preference 19: 539–564.

James, S. and Burton, M. (2003). Consumer preferences for GM food and other attributes of the food system. The Australian Journal of Agricultural and Resource Economics 47(4): 501–518.

Lancaster, K. J. (1966). A New Approach to Consumers Theory. Journal of Political Economy 74(2): 132–157.

Lancsar, E., Fiebig, D. G. and Hole, A. R. (2017). Discrete Choice Experiments: A Guide to Model Specification, Estimation and Software. Pharmaco Economics 35: 697–716.

Louviere, J.J., Flynn, T.N. and Carson, R.T. (2010). Discrete Choice Experiments Are Not Conjoint Analysis. Journal of Choice Modelling 3(3): 57–72.

Louviere, J.J., Hensher, D. and Swait, J.D. (2000). Stated Choice Methods: Analysis and Applications, Cambridge University press, Cambridge, UK.

Kjær, T. (2005). A review of the discrete choice experiment - with emphasis on its application in health care. Sydansk Universitet. Health Economics Papers 1: 1–139.

Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jacobsen, B., Liebe, U., Olsen, S.B., Sagebiel, J. and Thiene, M. (2021). Environmental Valuation with Discrete Choice Experiments, Guidance on Design, Implementation and Data Analysis. Switzerland: Springer.

Marsh, D., Mkwara, L. and Scarpa, R. (2011). Do Respondents' Perceptions of the Status Quo Matter in Non-Market Valuation with Choice Experiments? An Application to New Zealand Freshwater Streams. Sustainability 3: 1593–1615.

McFadden, D. (1973) Conditional Logit Analysis of Quantitative Choice Behaviour. In: Zarembka, P., Ed., Frontiers in Econometrics, Academic Press, New York, pp. 105-142.

Mørkbak, M.R., Christensen, T. And Gyrd-Hansen, D. (2010). Choke Price Bias in Choice Experiments. Environ Resource Econ 45: 537–551

Nocella, G., Boecker, A., Hubbard, L. and Scarpa, R. (2012). Eliciting Consumer Preferences for Certified Animal Friendly Foods: Can Elements of the Theory of Planned Behavior Improve Choice Experiment Analysis?. Psychol. Mark. 29: 850–868.

Ortega, D. L., Hong, S. J., Wang, H. H. and Wu, L. (2016). Emerging markets for imported beef in China: Results from a consumer choice experiment in Beijing. Meat Science 121: 317–323.

Rasciute, S. and Pentecost, E. J. (2008). The Location of Foreign Direct Investment in the Central and Eastern European Countries: A Mixed Logit and Multilevel Data Approach. Dept Economics, Loughborough University, UK, Discussion paper series, 1–24.

Sarrias, M. and Daziano, R. (2017). Multinomial Logit Models with Continuous and Discrete Individual Heterogeneity in R: The gmnl Package. Journal of Statistical Software 79(2): 1–46.

Scarpa R., Ferrini S. and Willis K. (2005) Performance of Error Component Models for Status-Quo Effects in Choice Experiments. In: Scarpa R., Alberini A. (eds) Applications of Simulation Methods in Environmental and Resource Economics. The Economics of Non-Market Goods and Resources, vol 6. Springer, Dordrecht.

Scarpa, R., Zanoli, R., Bruschi, V. and Naspetti, S. (2013). Inferred and stated attribute non-attendance in food choice experiments. Am. J. Agric. Econ. 95(1): 165–180.

Train, K. (2009). Discrete choice methods with simulation, 2nd ed. New York: Cambridge University Press.

Twaddle, H., A. (2011). Stated preference survey design and pre-test for valuing influencing factors for bicycle use. Master's thesis, Institute of transportation - Technische Universität München.

Vojáček, O. and Pecáková, I. (2010). Comparison of discrete choice models for economic environmental research. Prague economic papers 1: 35-53.

Wang, J., Ge, J. and Ma, Y. (2018). Urban Chinese Consumers' Willingness to Pay for Pork with Certified Labels: A Discrete Choice Experiment. Sustainability 10(603): 5–14.

Zeileis, A. and Hothorn, T. (2002). Diagnostic Checking in Regression Relationships. R News 2(3): 7–10. https://CRAN.R-project.org/doc/Rnews/.

Farmers' Motivations for Implementing Herpetofauna-Friendly Practices in Slovenia

Katja Konc, Tanja Šumrada and Živa Alif

Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana, Slovenia, (katja.konc@bf.uni-lj.si)

ABSTRACT

Herpetofauna populations in the EU are still declining, with agriculture identified as a key pressure. Farmers, as stewards of cultural landscapes, play an important role in biodiversity conservation. Using Self-Determination Theory (SDT), we explored how different types of motivation influence implementation of nature-friendly practices. We surveyed 462 farmers from Central and NE (Pomurje) Slovenia about their knowledge and attitudes toward herpetofauna, implementation of beneficial practices for their conservation (e.g., hedgerows and fishless ponds), and their motivations for these practices. Structural Equation Modelling revealed that integrated regulation, the most autonomous extrinsic motivatior, was the only significant positive predictor of conservation practices, suggesting that farmers implement these practices because they are embedded in their lifestyle and traditions. In an extended model including attitudes and nature connectedness, both intrinsic and integrated regulation had significant positive effects, with integrated regulation being twice as influential. Intrinsic motivation was shaped by attitudes and nature connectedness, while attitudes were also influenced by nature connectedness. These findings highlight the importance of focusing on traditional practices and internalization of conservation practices, rather than relying solely on financial incentives.

INTRODUCTION

Around 30 % of amphibian species and around 20 % of reptile species in EU are experiencing population decline (European Environment Agency, 2020). While there are still many knowledge gaps in regard to their conservation status, it has been established that agriculture through landuse change and intensification, the use of plant protection products, and other activities represents a key pressure on these two groups. The herpetofauna also faces numerous other threats, such as traffic, urbanization, species trafficking, invasive alien species, changes in water regimes, and climate change (European Environment Agency, 2020). 35 % of aquatic amphibian recorded locations and 28 % of reptile recorded locations in Slovenia were found on agricultural land (Zamolo et al., in print). Agriculture can support the conservation of these species through nature-friendly practices, with farmers playing a key role (Pe'er et al., 2014). Farmers may differ in their motivations for implementing conservation practices, for example some are driven by economic incentives such as scheme payments, others by moral concerns, or by various other factors and combinations thereof (Raymond et al., 2016). Research shows that motivations and attitudes influence farmer's willingness to participate in Agri-Environmental Schemes (AES) (Greiner & Gregg, 2011; Greiner, 2015). Identifying what motivates farmers to adopt nature-friendly practices that are beneficial for herpetofauna helps tailor conservation strategies and could help design new schemes in Common Agricultural Policy (CAP) (de Snoo et al., 2013; Propper et al., 2020).

Self-Determination Theory (SDT) is a well-established framework for understanding human motivation, emphasizing a continuum from controlled to autonomous regulation of behaviour (Ryan & Deci, 2000; Deci et al., 2017). While intrinsic motivation reflects a natural tendency to explore and engage with the world out of interest, extrinsic motivation stems from external rewards or pressures, and amotivation represents a lack of intent. The degree of internalization varies across four types of extrinsic regulation – external, introjected, identified, and integrated – with the latter two considered more autonomous. Higher internalization, especially intrinsic, identified, and integrated motivation, is linked to greater wellbeing, persistence, and creativity, particularly when basic psychological needs (autonomy, competence, relatedness) are met. Though widely used, SDT is relatively new to environmental psychology (Cooke et al., 2016). Studies suggest that autonomous motivation is the one that promotes intention for proenvironmental behaviour (Aviste & Niemiec, 2023; Barszcz et al., 2023; Cooke et al., 2016), and in agriculture, Zhu & Chen (2024) found that internalized motivation encouraged the adoption of low-carbon production, except for integrated regulation, which had a weaker effect. Another important factor in studies of environmental behaviour is nature connectedness, which is grounded in the biophilia hypothesis (Wilson, 2007). This hypothesis suggests that humans have an innate tendency to seek connection with nature. However, individuals differ in how strongly they experience this connection, which may help explain variations in proenvironmental behaviour (Mayer & Frantz, 2004). Nature connectedness can also be seen as a way of fulfilling the SDT need for relatedness (Weinstein et al., 2009). We designed a theoretical framework (Fig 1) that proposes that both extrinsic and intrinsic motivation influence farmers' intention for conservation behaviour, with nature connectedness influencing intrinsic motivation directly and indirectly via positive attitudes.

MATERIAL AND METHODS

The study was conducted through surveys with farmers in two project regions: NE (Pomurje) and Central Slovenia. The survey followed a structured questionnaire consisting of six sections. The first section introduced the research purpose and ethical considerations, after which consent and farm identification number were obtained. The second section assessed participants' knowledge and attitudes toward selected amphibian and reptile species using species identification tasks and Likert scale evaluations of how comfortable they are when they encounter the given species. Questions on ecological knowledge and attitudes were adapted from Ríos-Orjuela et al. (2020) and Ghosh & Basu (2022). In the third section, farmers reported their implementation of 12 herpetofauna-friendly practices (such as hedgerows, ponds, compost piles, reduced use of pesticides). Motivations for these practices were assessed in the fifth section based on Self-Determination Theory. Scales adapted from Pelletier et al. (1998) and Zhu & Chen (2024) measured intrinsic motivation, amotivation, and various types of extrinsic regulation. Each construct included a set of statements (e.g., "I engage in herpetofauna-friendly practices because they help preserve the character of my local area"), rated on a 7-point Likert scale from "Does not apply at all" (1) to "Fully applies" (7). Nature connectedness was measured using the 11-item Commitment to Nature Scale (Davis et al., 2009). Numerous scales for measuring nature connectedness have been developed and compared (Tiscareno-Osorno et al., 2023), including the Commitment to Nature Scale. We selected this scale over others because it is relatively short and includes items that we considered more accessible and understandable for the farmers. The scale reflects a broader, general sense of emotional and attitudinal affiliation with nature, as opposed to the attitudes measured in our study, which were focused on herpetofauna. The final section gathered demographic and farm-related information.

Data was collected between April and June 2024. Surveys were conducted on-site at advisory offices following farm subsidy consultations. A total of 231 farmers from each region participated (462 farmers in total). While farms in our sample did not differ significantly in size when compared to the whole population of farmers in both areas, they on average had younger managers and had higher rates of enrolment in agri-environmental schemes.

Table 1. Socio-demographic characteristics of farmers in the sample and the total population (means and standard deviations (SD) are calculated, except where number and proportion (%) are indicated).

	Sample	Population	p-value
Number of farms (n)	462	8686	
Average age	56.69 (12.90)	63.80 (14.2)	**<0.001**
Average farm intensity	0.87 (1.05)	0.89 (10.2)	0.893
Average farm size (ha)	13.38 (17.38)	13.35 (79.3)	0.981
Gender (M)	327 (72.2 %)	5950 (70.3 %)	0.722
Livestock farms	273 (59.3 %)	5918 (58.1 %)	**<0.001**
Enrolment in AES	157 (34.7 %)	1794 (20.7 %)	**<0.001**
Enrolment in Eco	38 (8.3 %)	403 (4.6 %)	**<0.001**

We first screened the data and excluded respondents with more than 10 % missing values (9 participants). All non-normally distributed variables (attitudes, motivations, and nature connectedness) were transformed using the Box-Cox method. Remaining missing values were imputed using classification and regression trees. To create a measure of farmers' nature-friendly behaviour, we calculated the average number of points they reached in the questions on their practices that were measured on a scale from 1 to 3. For other constructs, we applied factor analysis to reduce dimensionality. Confirmatory factor analysis (CFA) was used for motivation types and nature connectedness, as these are established constructs (Kline, 2023). Exploratory factor analysis (EFA) was used for attitudes toward herpetofauna, where dimensionality was not pre-defined (Fabrigar & Wegener, 2011). To test the theoretical model (Fig 1), we employed Structural Equation Modelling (SEM), a multivariate technique that combines factor and path analysis to evaluate relationships among observed variables and latent constructs (Kline, 2023). SEM allowed us to assess both measurement models and structural paths, providing insight into how attitudes, motivations, and contextual factors influence the intention of conservation behaviour.

RESULTS

Implementation rates of nature-friendly practices on Slovenian farms varied significantly between practice types. While 83 % and 80 % of farms do not use plant protection products along the borders and in the garden, only 3 % have two or more fishless ponds. In addition to not using plant protection products, most farmers reported working exclusively during daylight hours. Although this question was not asked in the context of conservation, such timing along with being attentive to amphibians on the road may have implications for amphibian safety during migration periods. The practices that most farmers partially or occasionally implement include compost piles and the non-use of rodenticides. The presence of grassland strips and hedgerows and their management so that shrub undergrowth remains is more common than not having any. The presence of small structural elements such as piles of wood and rocks, grassland strips along hedgerows and fishless ponds are never implemented by most farmers (Table 2).

We analysed farmers' motivations using confirmatory factor analysis (CFA). Due to poor model fit, several items with low factor loadings were removed. The construct of amotivation showed low discriminant validity due to high negative correlations, especially with introjected regulation, and was therefore excluded from further analysis. With the exception of external regulation (M = 3.6, SD = 1.56), farmers showed high levels of autonomous motivation (intrinsic: M = 5.51, SD = 1.32; integrated: M = 5.63, SD = 1.49; identified: M = 5.56, SD = 1.32; introjected: M = 5.25, SD = 1.51). All standardized factor loadings in the measurement models (with and without the additional constructs: connectedness to nature and attitudes toward amphibians and reptiles, excluding snakes) were significant and above the recommended 0.60 threshold, with two exceptions still above 0.40. Convergent and discriminant validity were satisfactory, and both models showed good fit (Fig 1, Table 3).

Table 2. Frequency of imple*ment*ation of herpetofauna conservation practices on the surveyed farms (n=462).

	Never/nowhere	Sometimes/somewhere	Always/everywhere
No usage of pesticides in the garden	6 %	15 %	80 %
No usage of pesticides near hedgerows	7 %	10 %	83 %
Working only during the day	7 %	14 %	79 %
Attention at animals on roads	5 %	23 %	72 %
Compost piles*	35 %	51 %	14 %
No usage of rodenticides	20 %	42 %	37 %
Maintaining hedgerows	39 %	30 %	31 %
Maintaining hedgerow undergrowth	46 %	31 %	23 %
Grassland strip	48 %	27 %	25 %
Piles of wood and rocks*	71 %	17 %	13 %
Grassland strip along hedgerows	51 %	27 %	22 %
Fishless ponds*	85 %	12 %	3 %

* In the case of compost piles, piles of wood and rocks and fishless ponds, the response categories for frequency were: "None", "One", and "Two or more".

The first structural model showed good fit (χ^2 = 345.8, CFI = 0.946, TLI = 0.930, RMSEA = 0.071, SRMR = 0.069). Integrated regulation was the only significant positive predictor of conservation practices (Table 4). The second model, extended to include connectedness to nature and attitudes toward amphibians and lizards as predictors of intrinsic motivation (including a mediation effect), also fit well (χ^2 = 1641.0, $p < 0.001$, CFI = 0.910, TLI = 0.900, RMSEA = 0.065, SRMR = 0.091). Both intrinsic and integrated regulation significantly predicted conservation practices, with integrated regulation being twice as influential. Intrinsic motivation was positively influenced by both attitudes and nature connectedness, the latter having a four times stronger effect. Nature connectedness also had a positive effect on attitudes, through which it indirectly affected intrinsic regulation.

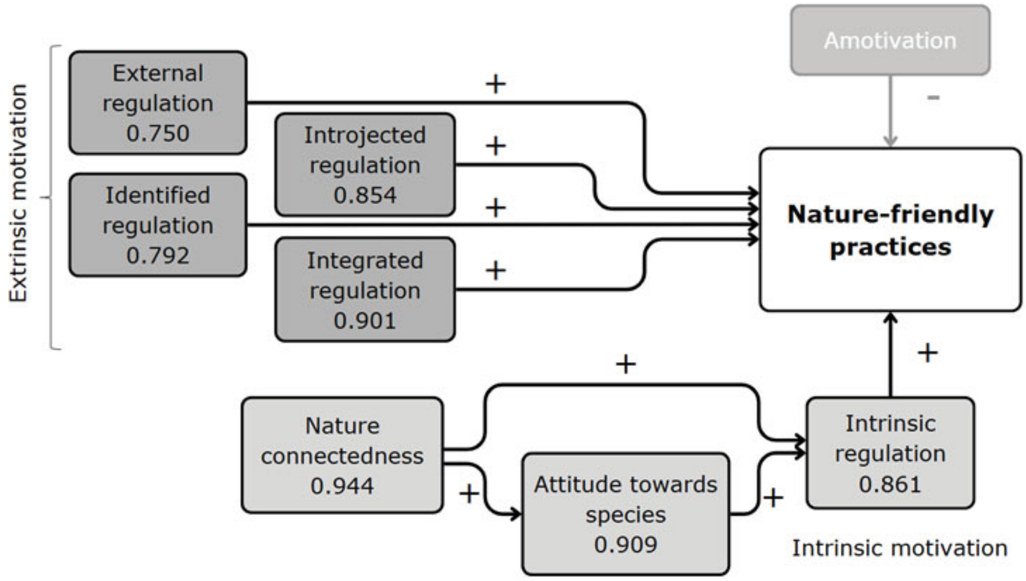

Figure 1. The theoretical framework developed for the study (Mayer & Frantz, 2004; Ryan & Deci, 2000; Weinstein et al., 2009; Zhu & Chen, 2024). The plus and minus signs indicate the expected polarity (negative/positive) of the effect. Composite reliability is written inside each construct. Amotivation showed low discriminant validity due to high negative correlations and was therefore excluded from further analysis.

Table 3. Discriminant validity of the latent constructs.

	Intrinsic	Nature connectedness	Attitudes	External	Introjected	Identified	Integrated
Intrinsic	0.78						
Nature connectedness	0.66	0.81					
Attitudes	0.30	0.25	0.79				
External	0.03	0.05	0.01	0.66			
Introjected	0.45	0.69	0.17	0.30	0.81		
Identified	0.44	0.66	0.17	0.24	0.73	0.74	
Integrated	0.38	0.58	0.14	0.03	0.64	0.57	0.87

Table 4. Results of structural model (regression paths) for the standard and extended model.

		Standard model			**Extended model**		
Dependent variable	Independent variable	coefficient	SE	p-value	coefficient	SE	p-value
Practices	External regulation	-0.01	0.02	0.369	-0.02	0.02	0.321
Practices	Introjected regulation	0.05	0.03	0.121	0.04	0.03	0.094
Practices	Identified regulation	-0.01	0.02	0.658	-0.01	0.02	0.637
Practices	Integrated regulation	0.07	0.03	**0.008**	0.06	0.02	**0.001**
Practices	Intrinsic regulation	0.02	0.04	0.496	0.03	0.01	**0.003**
Intrinsic regulation	Attitudes				0.20	0.06	**0.000**
Intrinsic regulation	Nature connectedness				0.84	0.08	**0.000**
Attitudes	Nature connectedness				0.26	0.05	**0.000**

DISCUSSION

The results highlight that conservation behaviour among farmers in cultural landscapes is primarily driven by more autonomous forms of motivation particularly integrated regulation and, to a lesser extent, intrinsic motivation. The current implementation of practices on Slovenian farms strongly depends on the complexity of the practice. Overall, farmers are partially driven by enjoyment and care for nature, but more strongly by external factors such as tradition and identity. This suggests that conservation practices are not merely seen as external obligations but are also often perceived as part of farmers' values and self-identity. External forms of motivation did not significantly predict conservation behaviour, which is in line with literature that states that farmers often see themselves as stewards of the land (Raymond et al., 2016), rather than as actors responding to external pressures or rewards.

The strong mediating role of nature connectedness and attitudes towards amphibians and lizards provides an important addition to motivational models. These findings suggest that affective and relational ties to nature may be critical in fostering deeper forms of motivation. Nature connectedness in particular emerged as a powerful driver, influencing not only attitudes but also motivation (Mayer & Frantz, 2004). Intrinsic motivation is fostered when three basic psychological needs are met: relatedness, autonomy, and competence (Ryan & Deci, 2019). Increasing intrinsic motivation – for example, through relationship building – may help encourage the adoption of new practices.

From a practical standpoint, these insights imply that policies aiming to promote conservation in cultural landscapes should not rely solely on economic incentives, that could either increase or decrease motivations (de Snoo et al., 2013), but should also consider strengthening farmers' emotional and identity based connections with nature. Environmental education, community based conservation programs, and participatory approaches that validate local knowledge and identity may help reinforce these internal drivers (Admiraal et al., 2017; Šumrada et al., 2021; Zhu & Chen, 2024).

To conclude, farmers' implementation of nature-friendly practices such as hedgerows, ponds, and grassland strips appears to be primarily driven by autonomous motivation – both intrinsic and identified motivation – rather than by external rewards or pressure. Strengthening connections to nature and positive attitudes toward biodiversity may therefore support long-term conservation behaviour in cultural landscapes.

ACKNOWLEDGEMENT

This research was funded through the project EIP KROTA under the Cooperation measure, submeasure M16.5 - Environment and Climate Change, in the Rural Development Programme of the Republic of Slovenia 2014–2020. We'd like to thank the agricultural advisors who welcomed us in their offices and helped us encourage farmers to fill in the surveys.

REFERENCES

Admiraal, J. F., Born, R. J. G. V. D., Beringer, A., Bonaiuto, F., Cicero, L., Hiedanpää, J., Knights, P., Knippenberg, L. W. J., Molinario, E., Musters, C. J. M., Naukkarinen, O., Polajnar, K., Popa, F., Smrekar, A., Soininen, T., Porras-Gomez, C., Soethe, N., Vivero-Pol, J.-L. and Groot, W. T. D. (2017). Motivations for committed nature conservation action in Europe. Environmental Conservation 44(2): 148–157.

Aviste, R. P. and Niemiec, C. P. (2023). Antecedents of environmental values and pro-environmental behavior intentions: A self-determination theory approach. Journal of Environmental Psychology 88: 102023.

Barszcz, S. J., Oleszkowicz, A. M., Bąk, O. and Słowińska, A. M. (2023). The role of types of motivation, life goals, and beliefs in pro-environmental behavior: The Self-Determination Theory perspective. Current Psychology 42(21): 17789–17804.

Cooke, A. N., Fielding ,Kelly S. and and Louis, W. R. (2016). Environmentally active people: The role of autonomy, relatedness, competence and self-determined motivation. Environmental Education Research 22(5): 631–657.

Davis, J. L., Green, J. D. and Reed, A. (2009). Interdependence with the environment: Commitment, interconnectedness, and environmental behavior. Journal of Environmental Psychology 29(2): 173–180.

de Snoo, G. R., Herzon, I., Staats, H., Burton, R. J. F., Schindler, S., van Dijk, J., Lokhorst, A. M., Bullock, J. M., Lobley, M., Wrbka, T., Schwarz, G. and Musters, C. j. m. (2013). Toward effective nature conservation on farmland: Making farmers matter. Conservation Letters 6(1): 66–72.

Deci, E. L., Olafsen, A. H. and Ryan, R. M. (2017). Self-Determination Theory in Work Organizations: The State of a Science. Annual Review of Organizational Psychology and Organizational Behavior 4(4): 19–43.

European Environment Agency. (2020). State of nature in the EU. Publications Office of the European Union. https://www.eea.europa.eu/publications/state-of-nature-in-the-eu-2020

Fabrigar, L. R. and Wegener, D. T. (2011). Exploratory Factor Analysis. Oxford University Press.

Ghosh, D. and Basu, P. (2022). Collation of Indigenous and Local Knowledge as Evidence Base for Herpetofauna Conservation Outside Protected Areas: Case Study from an Agricultural Landscape in Eastern India. Proceedings of the Zoological Society 75(2): 161–172.

Greiner, R. (2015). Motivations and attitudes influence farmers' willingness to participate in biodiversity conservation contracts. Agricultural Systems 137: 154–165.

Greiner, R. and Gregg, D. (2011). Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: Empirical evidence from northern Australia. Land Use Policy 28(1): 257–265.

Kline, R. B. (2023). Principles and practice of structural equation modeling. Guilford publications. https://www.guilford.com/books/Principles-and-Practice-of-Structural-Equation-Modeling/Rex-Kline/9781462551910

Mayer, F. S. and Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. Journal of Environmental Psychology 24(4): 503–515.

Pe'er, G., Dicks, L. V., Visconti, P., Arlettaz, R., Báldi, A., Benton, T. G., Collins, S., Dieterich, M., Gregory, R. D., Hartig, F., Henle, K., Hobson, P. R., Kleijn, D., Neumann, R. K., Robijns, T., Schmidt, J., Shwartz, A., Sutherland, W. J., Turbé, A., … Scott, A. V. (2014). EU agricultural reform fails on biodiversity. Science 344(6188): 1090–1092.

Pelletier, L. G., Tuson, K. M., Green-Demers, I., Noels, K. and Beaton, A. M. (1998). Why Are You Doing Things for the Environment? The Motivation Toward the Environment Scale (MTES)1. Journal of Applied Social Psychology 28(5): 437–468.

Propper, C., Hardy, L., Howard, B., Flor, R. and Singleton, G. (2020). Role of Farmer Knowledge in Agroeco-system Science: Rice Farming and Amphibians in the Philippines. Human–Wildlife Interactions 14(2).

Raymond, C. M., Bieling, C., Fagerholm, N., Martin-Lopez, B. and Plieninger, T. (2016). The farmer as a landscape steward: Comparing local understandings of landscape stewardship, landscape values, and land management actions. Ambio 45(2): 173–184.

Ríos-Orjuela, J. C., Falcón-Espitia, N., Arias-Escobar, A., Espejo-Uribe, M. J. and Chamorro-Vargas, C. T. (2020). Knowledge and interactions of the local community with the herpetofauna in the forest reserve of Quininí (Tibacuy-Cundinamarca, Colombia). Journal of Ethnobiology and Ethnomedicine 16(1): 17.

Ryan, R. M. and Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. The American Psychologist 55(1): 68–78.

Ryan, R. M. and Deci, E. L. (2019). Chapter Four - Brick by Brick: The Origins, Development, and Future of Self-Determination Theory. In A. J. Elliot (Ed.), Advances in Motivation Science 6: 111–156.

Šumrada, T., Vreš, B., Čelik, T., Šilc, U., Rac, I., Udovč, A. and Erjavec, E. (2021). Are result-based schemes a superior approach to the conservation of High Nature Value grasslands? Evidence from Slovenia. Land Use Policy 111a. 105749.

Tiscareno-Osorno, X., Demetriou, Y., Marques, A., Peralta, M., Jorge, R., MacIntyre, T. E., MacIntyre, D., Smith, S., Sheffield, D., Jones, M. V., Beckmann, J. and Schönbach, D. M. I. (2023). Systematic Review of Explicit Instruments Measuring Nature Connectedness: What Do We Know and What is Next? Environment and Behavior 00139165231212321.

Weinstein, N., Przybylski, A. K. and Ryan, R. M. (2009). Can Nature Make Us More Caring? Effects of Immersion in Nature on Intrinsic Aspirations and Generosity. Personality and Social Psychology Bulletin 35(10): 1315–1329.

Wilson, E. O. (2007). Biophilia and the Conservation Ethic. In Evolutionary Perspectives on Environmental Problems. Routledge.

Zamolo, A., Vamberger, M., Vek, M., Kirbiš, N., Lipovšek, G., Poboljšaj, K., & Lešnik, A. (in print). Poznavanje, ogroženost in varstvo dvoživk in plazilcev v kmetijski krajini. In T. Šumrada, T. Čelik, I. Rac, U. Šilc, & A. Udovč (Eds.), Varstvo biotske pestrosti in okolja v kmetijski krajini. Pristopi in izzivi v Sloveniji. Založba ZRC.

Zhu, Y. and Chen, J. (2024). How do we motivate farmers to adopt low-carbon production? Analysis of extrinsic incentives' internalization. Journal of Environmental Psychology 94: 102186.

Compiling New Sustainability Data on FADN Farms in Slovenia: a Small-scale Feasibility Study

Maja Kožar[1], Sara Bele[1], Matej Bedrač[1] and Ilona Rac[2]

[1] Agricultural Institute of Slovenia, Agricultural Economics Department, Hacquetova ulica 17, Ljubljana, Slovenia, (maja.kozar@kis.si)

[2] University of Ljubljana, Biotechnical Faculty, Jamnikarjeva 101, Ljubljana, Slovenia

ABSTRACT

The paper presents selected outcomes of a national project supporting the conversion of FADN (Farm Accountancy Data Network) to FSDN (Farm Sustainability Data Network) in Slovenia, involving the compilation of a limited amount of new farm-level sustainability data on a sample of real FADN farms. The aim was to test "FSDN-like" processes on real farms (data collection and compilation, data sharing, improving farm feedback report and advisory service, etc.) in the Slovenian context in order to provide concrete recommendations for the timely and comprehensive conversion to FSDN in Slovenia. An overall conclusion is that maintaining the status quo approach to data compilation after the conversion to FSDN (majority of data collection burden remaining on farms, weak or non-existent data sharing) would be very time consuming, expensive and endangering for the core FADN through lower willingness of the farmers to participate. Recommendations include proposals for significant systemic and organizational changes in the FADN/FSDN, significant strengthening of data sharing (interoperability of already existing databases), digitization and optimization of key processes, and training of data collectors, farm advisors and farmers.

INTRODUCTION

Conversion to FSDN (Farm Sustainability Data Network) is the most comprehensive change of FADN (Farm Accountancy Data Network) in history. While the FADN system was primarily focused on collecting micro-economic farm-level data, the conversion to FSDN means an extension to new farm sustainability topics, mainly environmental and social, which will allow for a more comprehensive assessment of the sustainability of agriculture at the level of agricultural holdings (Regulation 2023/2674, 2023). The FSDN comprises 42 farm sustainability topics: 18 economic, 16 environmental and 8 social topics (Annex I of Regulation 2023/2674, 2023; Rossi, 2024). Altogether, with FSDN 22 new (farm-level) data tables are added to farm return; the tables mostly represent groups of variables/information (Annex VIII of Implementing Regulation No. 2024/2746, 2024; Rossi, 2024).

Through this conversion the FADN/FSDN database, with a harmonised methodology for all European Union (EU) countries, further strengthens its position as the most important farm-level database for the assessment of farm sustainability, for supporting evidence-based policy creation and evaluation, as well as for the upgrading the farm advisory service (Strategic Dialogue on ..., 2024; A Vision for Agriculture and Food, 2025). The ambition is also to develop "a voluntary benchmarking system for on-farm sustainability assessments" or an "on-farm Sustainability Compass", which could also help reduce administrative burdens for farmers through strengthened data sharing (A Vision for Agriculture and Food, 2025).

In this paper, we present selected outcomes of a national project, which was aimed at supporting the conversion of FADN to FSDN system in Slovenia (Kožar et al., 2024a and 2024b). Before the conversion to FSDN, the Slovenian FADN system faced significant challenges in various respects. One of them is the fact that the majority of the data collection burden still lies on the participating farmers. With the increased data requirements expected within the FSDN framework, this could weaken farmers' participation in the system and endanger the FADN/FSDN sample (and data quality) in the long term. One of the aims of the project, which produced an extensive range of outcomes (listed in Kožar et al., 2024a), was to test the compilation of a smaller quantity of new farm-level sustainability data on existing FADN farms in order to provide recommendations for the timely and comprehensive conversion to FSDN in Slovenia. In essence, the ambition was to test the "FSDN-like" processes on real farms (data collection, data sharing, farm feedback and advisory service, etc.) in the Slovenian context.

MATERIAL AND METHODS

The sample of real (surveyed) farms participating in the project was purposive by design and not representative of the FADN population in Slovenia. The reasons for this were limited time and resources within the project, as well as typically low willingness of farmers to participate (Kožar et al., 2024a). Furthermore, the aim of the project was not to produce accurate values for the new sustainability data/indicators, but to test "FSDN-like" processes of data compilation on real farms. The criteria for selecting FADN farms in the surveyed sample included representation of the most important types of farming and economic size classes of agricultural holdings, location (inclusion of agricultural holdings in areas with natural or other specific constraints (ANC)), as well as the inclusion of organic and small farms. The initial sampling list contained 55 farms, while the final list included 22 farms that were willing to cooperate in our survey. 6 of the surveyed farms were engaged in crop production, 15 in livestock production, and one surveyed farm had mixed production; 19 surveyed farms were located in ANC areas, and 5 farms had organic production. Selection of the participating farms was executed by the staff of one of the FADN accounting offices under the Chamber of Agriculture and Forestry of Slovenia (also part of the project team); more details are available in Kožar et al. (2024a).

The next phase was the selection and prioritization of tested farm-level sustainability indicators, for which the data compilation processes were tested on surveyed FADN farms. The selection process started with the review of the indicator list proposed in autumn 2022 within the EU-funded IPM2–FSDN pilot project (FSDN Workshop, 2022) and of the indicator list proposed by previous national research (Kožar et al., 2022; this set of indicators was based on the indicator list and outcomes of the FP7 project FLINT: Kelly et al., 2015; Vrolijk and Poppe, 2021). The project team and data collectors conducted several rounds of revisions and simplifications of the proposed indicators through workshops, working meetings and testing of the questionnaire. Attention was devoted to compiling a list of indicators that would be supported as much as possible with existing databases in order to reduce the burden on farmers. Some indicators were not tested in the project, either because they were not relevant in the Slovenian context, were too complex or not feasible within the project timeline or data were already existent in other databases, etc.

The list of the tested farm-level sustainability indicators was finalized by June 2023 as per the project timeline. It needs to be added that the first proposal of the new FSDN variables by the European Commission was circulated in Autumn 2023 and agreed with the EU Member States by the end of September 2024 (Implementing Regulation No. 2024/2746, 2024).

Data was collected for the accounting year 2022 with the help of in-person surveys (data collected directly on the surveyed farms) and pre-filled sustainability data (data from „data sharing", i.e. from existing administrative and other databases). In-person surveys on farms were conducted between June and September 2023, whereas the completion, processing and validation of data were completed by the beginning of 2024. Data compilation was performed by data collectors, who were part of the project team and employed at one of the accounting offices. They had a lot of experience in FADN and direct work with farms, which saved a lot of time. Data collectors were instructed to provide informed consent from the surveyed farms, to collect certain general data about the surveyed farms, and to collect information about data compilation process (measure duration of different phases, report key obstacles in the processes, etc.). Additionally, they were requested to pre-fill data from the existing databases for the surveyed farms and to enter data digitally by default, i.e. in an electronic file, rather than on paper.

Several other aspects of farm-level data compilation in the light of the conversion to FSDN were analysed in the project, such as accessibility/convertibility and interoperability of databases for (Slovenian) agriculture, as well as strengthening the agricultural advisory service in the field of farm sustainability performance. Lastly, a very rough estimate of additional time and costs of compiling new farm-level sustainability data compared to the costs of collecting only FADN data was made, with unchanged approach to data compilation (majority of data collection burden on farms, weak or non-existent data interoperability, etc.).

RESULTS

The final list of farm-level sustainability indicators, for which the data was compiled on the surveyed farms, included 38 indicators (Fig. 1.): 11 indicators cover economic, 15 environmental, and 12 social aspect of farm sustainability; additionally, some general (basic) data on surveyed farms were collected. All the tested indicators are listed in the Annex. Compared to the corresponding new FSDN variables (Annex VIII of Implementing Regulation No. 2024/2746, 2024), the majority of the tested indicators are highly comparable (same or similar) in terms of required data or covering similar topics.

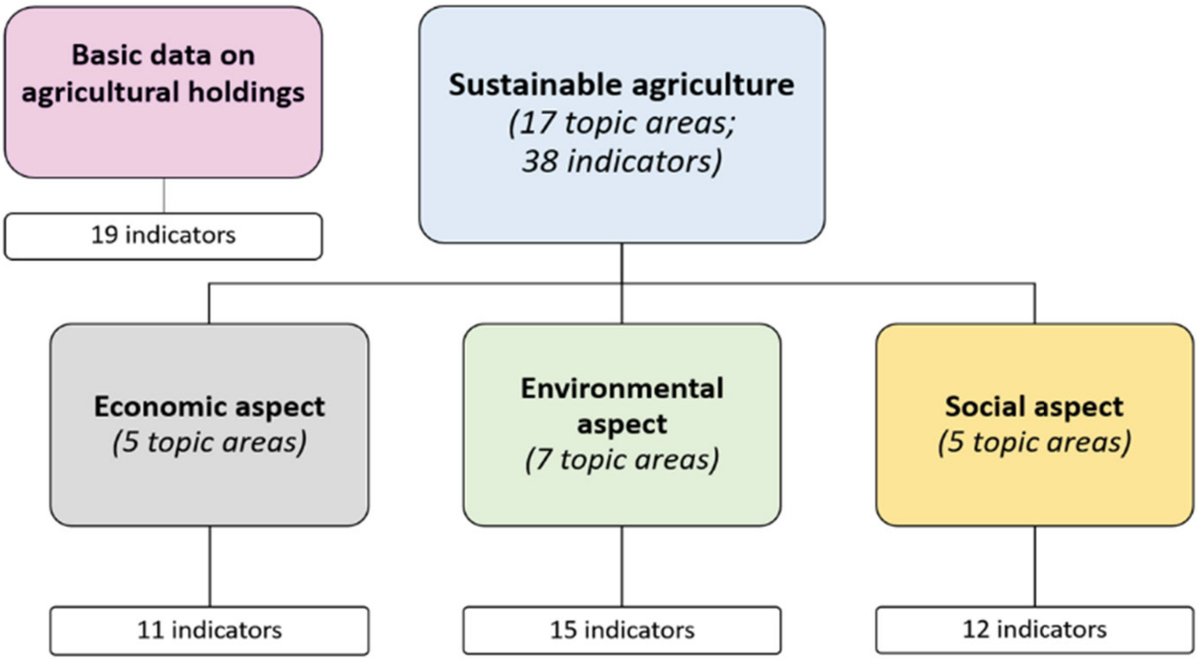

Figure 1. Number of tested indicators by farm sustainability aspect and number of basic data on agricultural holdings, final list (all indicators listed in Annex).

Source: Kožar et al. (2024a)

Since the sample of surveyed farms was not representative by design, we do not present the absolute values of the selected compiled data/indicators in this paper. These values could only be used orientationally as rough estimates and would need to be interpreted with caution. Nevertheless, based on the data compiled, the farm-level feedback (benchmarking) report was upgraded: in addition to key FADN results, the new sustainability indicators were added, and a "dashboard" style, benchmarking elements and more attractive, graphical layout were used. Furthermore, two workshops with the surveyed farms and one workshop for agricultural advisors were conducted, where the compiled indicators, an upgraded farm feedback report, and other relevant project outcomes, such as a step-by-step proposal of advisory service based on the collected farm sustainability data, were presented (Kožar et al., 2024a).

The outcomes of data compilation on the surveyed farms confirmed that in-person data collection on farms would be very time-consuming (more than 5 hours per surveyed farm, of which cca. 3.5 hours for data collection, entry and basic data control). These and other relevant outcomes (e.g., Fig.2) were communicated to the European Commission during the negotiation process, with calls for a further reduction of the quantity of the required new data/variables within the FSDN (especially of the "survey" type of data), as well as for their simplification and stepwise introduction. Rough estimates showed that the costs of compiling additional (new) farm-level sustainability data could be higher for cca. two thirds or more compared to costs for the compilation of the “standard” FADN data (details in Kožar et al., 2024a).

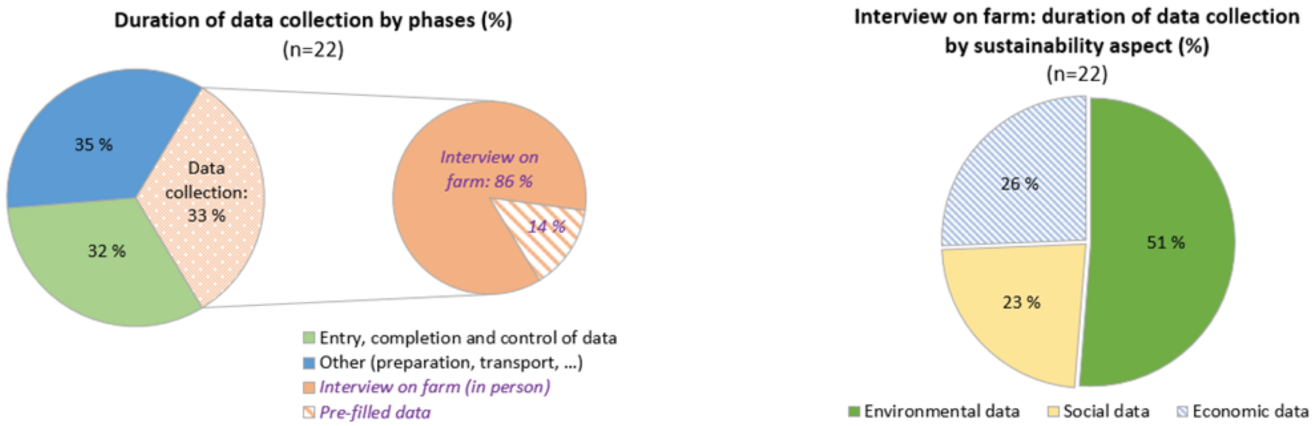

Figure 2. Estimated duration of data compilation for the preparation of test sustainability indicators on surveyed farms.
Source: Kožar et al. (2024a)

DISCUSSION

The compilation of the new sustainability data on real farms carried out in our project was an important and timely small-scale feasibility exercise of the "FSDN-like" processes for Slovenia, as it was conducted parallel to the FSDN process at the EU level, and several aspects of the conversion to FSDN in the Slovenian context were examined and tested.

Related to the presented project outcomes, some limitations need to be highlighted. The first limitation is the unrepresentative sample of surveyed farms (purposive sample), which disables generalization to the population of FADN holdings. A further limitation was the timing and short duration of the project (October 2022–September 2024): the project started well before the first proposal of the new FSDN variables (indicators) was circulated by the European Commission (finalized at the very end of the project, end of September 2024; Implementing Regulation No. 2024/2746; 2024). Thus, a complete alignment of sustainability indicators, tested in the project, with the final FSDN indicators (new FSDN variables) was not possible.

Nevertheless, the process of compiling the new sustainability data from real farms highlighted several important issues, such as the sensitivity of certain issues for farms, importance of communication with farms, staff specialization and skills – related to that, also the importance of good instructions and definitions of the requested data. Even with a small quantity of newly collected farm-level sustainability data, it was evident, that in Slovenia data sharing (interoperability) related to FADN and new sustainability data between different data-holders is weak or non-existent and that there are significant organizational and administrative challenges. Further, the challenges related to human resources (insufficient number of specialized staff, level of digital skills, etc.) were indicated.

An overall conclusion is that maintaining the status quo approach to data compilation in the FSDN system (weak data sharing, majority of data collection burden on participating farms; in the project this was emulated through in-person interviews on farms) would be very time consuming, expensive and likely endangering for the core FADN through lower willingness of the farmers to participate. Therefore, significant systemic and organizational changes at key stakeholders in the FADN/FSDN network were recommended. It is also crucial to significantly strengthen data sharing (interoperability), digitization and optimization of key processes, and lastly, training of data collectors, farm advisors and farmers (Kožar et al., 2024a).

ACKNOWLEDGEMENT

The paper presents the results of the project V5-2229 "Supporting evidence based agricultural policy in Slovenia: reinforcing core FADN and supporting activities for conversion to FSDN", supported by the Slovenian Research and Innovation Agency and the Ministry of Agriculture, Food and Forestry of the Republic of Slovenia. Authors would like to thank the farms and farm advisors participating in the project or in surveys, and to other members of the project team.

REFERENCES

A Vision for Agriculture and Food. (2025). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee of the Regions a Vision for Agriculture and Food Shaping together an attractive farming and agri-food sector for future generations. COM/2025/75 final. Brussels, 19.2.2025.

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025DC0075

FSDN Workshop. (2022). Conversion of Farm Accountancy Data Network into the Farm Sustainability Data Network. EU-funded IPM2–FSDN pilot project (lead contractor Ecorys). 3rd Stakeholders Workshop. Online workshop, October 22, 2022.

Implementing Regulation No. 2024/2746. (2024). Commission Implementing Regulation (EU) 2024/2746 of 25 October 2024 laying down rules for the application of Council Regulation (EC) No 1217/2009 setting up the Farm Sustainability Data Network and repealing Commission Implementing Regulation (EU) 2015/220.

http://data.europa.eu/eli/reg_impl/2024/2746/oj

Kelly, E., Ryan, M., Finn, J. and Hennessy, T. (2015). Farm-level indicators for evaluating sustainability and emerging new policy topics. A report on WP1 progress: Farm Level Indicators of Sustainability. Deliverable D 1.4 of 7FP project FLINT (Farm Level Indicators for New Topics in Policy Evaluation): 75 pg.

Kožar, M., Bedrač, M., Bele, S., Bleiweis, A., Brečko, J., Hiti Dvoršak, A., Moljk, B., Telič, V., Travnikar, T., Zagorc, B., Novak, A., Rac, I., Šumrada, T., Tomšič, M., Žgajnar, J., Cör, T., Demšar-Benedičič, A., Šnut, L., Šenk, D. and Beguš, M. (2024a). Podpora na dejstvih utemeljeni kmetijski politiki v Sloveniji: krepitev osnovnega FADN in podpora pri prehodu v FSDN (Supporting evidence based agricultural policy in Slovenia: reinforcing core FADN and supporting activities for conversion to FSDN). Final report. Ljubljana: Kmetijski inštitut Slovenije, Univerza v Ljubljani, Biotehniška fakulteta; Kranj: KGZS − KGZ Kranj.

Kožar, M., Bele, S., Bedrač, M. And Cunder, T. (2022). Farm-level indicators for the evaluation of sustainable agriculture in Slovenia. In: TOMŠIČ, Marija (ur.), et al. (2022). Societal changes and their implications on agri-food systems and rural areas: proceedings of the Joint Conference of the Slovenian Association of Agricultural Economists (DAES) and the Austrian Association of Agricultural Economists (ÖGA): Ljubljana, September 22-23, 2022. Ljubljana: Association of Agricultural Economists of Slovenia (DAES): pp. 135-136. ISBN 978-961-94943-1-8.

https://www.daes.si/storage/category/FuE9aHblO8pg8MSrObsxvwQLMI6TKaT3kwXkf47V.pdf

Kožar, M., Zagorc, B., Telič, V., Bele, S., Bedrač, M., Demšar-Benedičič, A. and Rac, I. (2024b). Final outcomes of national project on compiling new sustainability data on FADN farms in Slovenia. Presentation at 29th PACIOLI workshop, October 6–9, 2024, Montegrotto Terme, Italy.

https://www.pacioli.org/PacioliImages/documents/1d9a7828-eef5-4d41-88fc-c1dbfea5e1d5.pdf

Regulation 2023/2674. (2023). Regulation (EU) 2023/2674 of the European Parliament and of the Council of 22 November 2023 amending Council Regulation (EC) No 1217/2009 as regards conversion of the Farm Accountancy Data Network into a Farm Sustainability Data Network.

http://data.europa.eu/eli/reg/2023/2674/oj

Rossi R. (2024). State of play of FSDN and potential analyses of FSDN data. Presentation at 29th PACIOLI workshop, October 6–9, 2024, Montegrotto Terme, Italy.

https://www.pacioli.org/PacioliImages/documents/2-1%20dgagri.pdf

Strategic Dialogue on the future of EU agriculture. (2024). A shared prospect for farming and food in Europe. The final report of the Strategic Dialogue on the future of EU agriculture. Strategic Dialogue on the Future of EU Agriculture. Brussels, September 2024.

https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/main-initiatives-strategic-dialogue-future-eu-agriculture_en

Vrolijk, H. and Poppe, K. (2021). Cost of Extending the Farm Accountancy Data Network to the Farm Sustainability Data Network: Empirical Evidence. Sustainability, 13(15): 8181.

ANNEX

Table 1. Final list of tested indicators of farm-level sustainability.

Economic indicators of farm-level sustainability (Nr. of topic areas: 5; Nr. of indicators: 11)	
Topic area	**Indicator name**
Innovation	Number and type of on-farm innovations
	Investments for on-farm innovations (novelties)
Risk management	Use of risk management tools
	Futures (contracts) for selling products
	Memberships in agricultural cooperatives or in other agricultural interest groups
Market integration, quality schemes	Marketing channels
	Direct sale of agricultural products
	Participation in food quality schemes
Total income of farm household, off-farm income	Average (net) hourly wage
	Disposable total income of farm household
Access to land	Renting of agricultural land
Environmental indicators of farm-level sustainability (Nr. of topic areas: 7; Nr. of indicators: 15)	
Topic area	**Indicator name**
Animal welfare	Access to yard
	Number of grazing days
Manure use and management	Import, export and production of manure on farm
	Manure storage
	Manure nitrogen loading of UAA (utilized agricultural area)
	Manure application techniques
Renewable energy	Renewable energy production
Organic farming	Share of sales of products sold as organic
Agricultural practices	Tillage management practices
	Plant residues removal
Water management	Irrigated area and water used for irrigation
	Use of drainage systems
Landscape features	Built landscape features
	Water landscape features
	Plant landscape features

Social indicators of farm-level sustainability (Nr. of topic areas: 5; Nr. of indicators: 12)	
Topic area	**Indicator name**
Generational renewal	Farm management
	The year of manager taking over the farm
	Farm succession
Work safety	Number of occupational accidents on the farm
Working conditions	Daily working hours of farm holder/manager
	Days of leave of farm holder/manager
Quality of life	Availability and access to basic services and infrastructure in the local environment
	Access to broadband internet connection in rural areas
Knowledge and training	Level of the general education of farm holder/manager
	Participation in EIP projects
	Other forms of informal training of farm household members
	Farm advisory services

Source: Kožar et al. (2024a)

Medium-term Outlook for the Croatian Beef and Veal Market Using the AGMEMOD Partial Equilibrium Model

David Kranjac[1], Krunoslav Zmaić[1], Tihana Sudarić[1], Lucija Pečurlić[1], Maja Petrač[1], Magdalena Zrakić Sušac[2], Marija Ravlić[1] and Emil Erjavec[3]

[1] Josip Juraj Strossmayer University in Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia, (david.kranjac@fazos.hr)

[2] University of Zagreb Faculty of Agriculture, Svetošimunska cesta 25, 10000 Zagreb, Croatia

[3] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana, Slovenia

ABSTRACT

This paper analyses the medium-term outlook of the Croatian beef and veal meat market using the AGMEMOD partial equilibrium model. Despite more than a decade of EU membership, Croatia's beef sector remains structurally weak, with declining production and increasing dependence on imports. Simulation results under the baseline scenario (2023–2030), which assumes a continuation of current CAP instruments and stable macroeconomic conditions, project a further drop in domestic production, from 38.4 thousand tonnes in 2023 to 30.1 thousand tonnes by 2030. Meanwhile, consumption is expected to rise, deepening the trade deficit and reducing the self-sufficiency rate from 60% to 52%. The results highlight the growing gap between domestic supply and demand, emphasizing the need for targeted structural and policy interventions to reverse this negative trend.

INTRODUCTION

Croatia, the last of the Central and Eastern European Countries (CEECs) to join the European Union (EU), became a full member on July 1st, 2013. Like many other post-communist member states, Croatia's agricultural sector is marked by structural dualism featuring both large-scale agricultural enterprises and a high prevalence of small family farms characterized by limited production capacity, low input use, and relatively low productivity. The integration into the EU's single market, the adoption of the Common Agricultural Policy (CAP), and the gradual convergence of domestic agricultural prices with those in the EU-27 created new opportunities and challenges for the sector (Erjavec et al., 2006). These processes were expected to stimulate modernization, improve competitiveness, and enhance market integration. However, after more than a decade of EU membership, Croatia continues to face significant structural and performance-related challenges in agriculture, particularly in the livestock sectors (Grgić et al., 2019.). Productivity growth has remained limited, and self-sufficiency levels have not improved. This is especially evident in key livestock markets, including the beef sector, where stagnating production levels, declining cattle numbers, and persistent reliance on imports reflect a broader inability to capitalize on available policy instruments and market potential (Table 1, 2, 3, 4).

Table 1. Number of cattle in the Republic of Croatia in the different categories (2013 – 2023)

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2023 vs 2013
Young cattle up to 1 year old	Calves for slau-ghter	19267	13126	19964	20147	20263	19412	19179	18604	19737	18744	18596	-3.5%
	Young female bovine	51689	52998	47067	53623	57081	61890	62449	60285	65248	58705	56215	8.8%
	Young male bovine	73806	65578	80959	81211	78524	73209	69956	66863	71346	70693	69949	-5.2%
	Total	**144762**	**131702**	**147990**	**154981**	**155868**	**154511**	**151584**	**145752**	**156331**	**148142**	**144760**	**0.0%**
Cattle from 1 to 2 years old	Heifers	37771	36750	38101	38847	40319	42061	49824	47116	47535	47242	54216	43.5%
	Heifers for slau-ghter	7450	8917	7296	6855	7115	7711	8688	9102	8734	9199	9429	26.6%
	Male bovine	46957	41585	42770	43063	52489	45689	48177	55082	50394	55895	51666	10.0%
	Total	**92178**	**87252**	**88167**	**88765**	**99923**	**95461**	**106689**	**111300**	**106663**	**112336**	**115311**	**25.1%**
Cattle older than 2 years	Heifers	12197	23246	27215	28123	28275	13907	14368	14601	14689	15167	15885	30.2%
	Heifers for slau-ghter	2004	1177	1645	1795	1805	985	1104	1128	1152	1130	1048	-47.7%
	Dairy cows	168025	159394	151502	146510	139443	135851	130025	109807	102333	79042	71423	-57.5%
	Other cows	13460	20886	18999	20320	21550	9503	11867	34088	39807	58758	59927	345.2%
	Other (bulls, oxen)	9806	16980	4574	4119	3893	3907	4602	6205	6612	7269	6850	-30.1%
	Total	**205492**	**221683**	**203935**	**200867**	**194966**	**164153**	**161966**	**165829**	**164593**	**161366**	**155133**	**-24.5%**
Cattle total		**442432**	**440637**	**440092**	**444613**	**450757**	**414125**	**420239**	**422881**	**427587**	**421844**	**415204**	**-6.2%**

Source: Croatian Bureau of Statistics 2013-2023

The Croatian beef and veal market remains heavily dependent on the import of live animals. In 2023, imports reached 41.9 thousand tonnes, compared to 42.3 thousand tonnes exported, yet the trade balance remains negative in value terms, with imports amounting to €142.5 million and exports only €118.2 million. This reflects a structural reliance on imported livestock to sustain domestic production and processing capacities (Table 2).

Table 2. Export and import of live cattle in the Republic of Croatia (2013 – 2023)

		Live animals											
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2023 vs. period avg.**
Export	Quantity (1000 t)	16.81	9.20	9.29	14.37	14.59	24.19	22.12	27.99	40.84	41.96	42.33	77%
	Value (EUR)	30.76	15.45	14.87	26.71	26.26	46.01	41.80	54.40	84.14	108.13	118.22	129%
Import	Quantity (1000 t)	21.57	20.39	23.31	22.41	27.27	26.74	31.19	30.30	37.14	35.80	41.86	45%
	Value (EUR)	57.27	52.76	60.85	58.41	74.49	74.55	83.69	79.11	99.53	111.84	142.50	75%

Source: Croatian Bureau of Statistics 2013-2023

Croatia is a net importer of beef and veal meat, with imports of fresh, chilled, and frozen beef significantly exceeding exports both in quantity and value (Kranjac et al., 2021). In 2023, import volumes reached 35.4 thousand tonnes, more than four times the export volume of 7.4 thousand tonnes. The value of imports (€203.5 million) was over five times higher than that of exports (€37.5 million), highlighting a growing trade deficit and the limited competitiveness of domestic beef and veal meat production (Table 3).

Table 3. Export and import of beef & veal meat in the Republic of Croatia (2013 – 2023

		Beef & veal meat fresh or chilled and frozen											
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2023 vs. period avg.**
Export	Quantity (1000 t)	3.35	4.18	4.33	6.54	5.85	7.58	7.66	6.22	6.66	7.09	7.36	21%
	Value (EUR)	12.07	15.99	18.13	25.25	24.60	32.05	34.13	26.63	31.37	39.32	37.49	39%
Import	Quantity (1000 t)	10.22	14.50	17.38	19.98	22.04	22.56	24.75	22.47	26.84	31.30	35.44	58%
	Value (EUR)	35.73	49.35	60.44	70.96	82.18	90.87	98.71	83.11	113.22	175.91	203.49	110%

Source: Croatian Bureau of Statistics 2013-2023

Domestic meat production declined from 47.3 to 38.4 thousand tonnes, while consumption remained consistently higher, averaging around 60 thousand tonnes annually. This imbalance has resulted in a continued reliance on imports, which peaked at 41.9 thousand tonnes in 2023. Although export volumes increased over the decade, they have not been sufficient to offset the trade deficit. Consequently, Croatia's self-sufficiency in beef and veal production fluctuated but ultimately declined to just 60% in 2023.

Table 4. Beef & veal meat market o*utloo*k in the Republic of Croatia (2013 – 2023)

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Live animals (000 heads)	442	441	440	445	451	414	420	423	428	422	415
Production (1000 t)	47,27	44,42	42,26	44,43	42,2	43,78	45,43	43,37	43,18	41,23	38,38
Domestic consumtpion (1000 t)	60,44	60,21	60,92	59,66	62,18	58,42	65,56	59,67	59,90	56,05	61,07
Import (1000 t)	21,57	20,39	23,31	22,41	27,27	26,74	31,19	30,30	37,14	35,80	41,86
Export (1000 t)	16,81	9,20	9,29	14,37	14,59	24,19	22,12	27,99	40,84	41,96	38,33
Neto export (1000 t)	-4,76	-11,19	-14,02	-8,04	-12,69	-2,54	-9,07	-2,31	3,70	6,16	-3,53
Self sufficiency	69%	67%	61%	63%	57%	70%	63%	70%	69%	71%	60%

Source: Author's calculation according to Croatian Bureau of Statistics 2013-2023

This paper aims to analyse the medium-term outlook of the Croatian beef sector by applying the AGMEMOD partial equilibrium model. By simulating market developments under a baseline scenario aligned with current CAP instruments, the research provides insights into expected trends in production, consumption, trade and self-sufficiency up to 2030.

MATERIALS AND METHODS

This study employs the AGMEMOD (Agriculture Member State Modelling) framework, a dynamic, econometric, partial equilibrium model that operates at the multi-country and multi-commodity level. Its primary objective is to provide medium-term market projections for key agricultural commodities, with a simulation horizon extending to the year 2030 (Salamon et al., 2019). The modelling approach follows a bottom-up structure, where individual country models developed according to a standardized template are integrated into a consolidated European Union-level model (Chantreuil et al., 2012). Each national model consists of several commodity specific sub-models that represent major agricultural sectors, including cereals (such as wheat, barley, and maize), oilseeds, livestock and meat (including cattle, beef, pigs, pork, poultry, sheep, and mutton), and dairy products (such as cheese, butter, whole milk powder, and skimmed milk powder).

In the case of Croatia, the sub-model used in this study is based on annual time series data covering the period from 1995 to 2023. These data were collected primarily from national institutions, such as the Croatian Bureau of Statistics (CBS, 2025). The underlying database includes variables related to production volumes, domestic use for food and feed, imports, and exports structured in the form of market balance sheets.

Each commodity market within the model is interconnected, allowing for the capture of competitive relationships among products for limited resources, as well as interactions between crop and livestock sectors. Supply, demand, trade flows, and prices are determined endogenously within the respective sub-models (Chantreuil et al., 2012). Country-specific models simulate the behaviour of economic agents (producers and consumers), respond to changes in exogenous drivers (e.g., macroeconomic indicators, technological developments, and policy instruments), and reflect market price dynamics. Based on a system of econometrically estimated equations, the model generates projections for endogenous variables using both historical data and assumed future trends in exogenous variables. The general form of the equations illustrates how supply and demand are modelled in the Croatian beef and veal sector inside AGMEMOD sub-model. The first set of equations represents how supply is modelled.

Number of cattle (i) produced from the breeding herd $cct_{i,t}$ can be expressed as follows:

$$spr_{i,t} = f(cct_{i,t-1}, ypa_{i,t}) \qquad i = 1, \dots, n \qquad (1),$$

where $spr_{i,t}$ represents number of cattle (*i*) produced by breeding herd $cct_{i,t}$, and $ypa_{i,t}$ represents yield of calves per cow (*i*) in year *t*.

The number of breeding cows (breeding herd) (i) is expressed as follows:

$$cct_{i,t} = f(cct^{k}_{i,t-1}, p_{i,t}, V) \qquad k = 1, \dots, n \quad i = 1, \dots, n \qquad (2),$$

where $cct^{k}_{i,t-1}$ represents the final stock of breeding cows (*i*) in year *t-1*, $p_{i,t}$ is the actual price of breeding cows (*i*) in year t, a V represents a vector of exogenous variables that can affect the number of breeding cows (*i*) (e.g. various political instruments such as state subsidies that are not part of the CAP).

Total beef and veal meat production (*i*) is derived from the average slaughter weight *j* multiplied by the number of slaughtered cattle *i*, and the number of slaughtered cattle can be expressed as follows:

$$ktt_{i,t} = \sum_j ktt^{j}_{i,t} \qquad i = 1, \dots, n \;\; j = 1, \dots, m \quad (3),$$

$$ktt^{j}_{i,t} = f(cct^{j}_{i,t}, p_{i,t}, z^{j}_{i,t}, V) \quad i = 1, \dots, n \;\; j = 1, \dots, m \quad (4),$$

where $ktt^{j}_{i,t}$ is the number of slaughtered cattle *i* in the current year *t*, $cct^{j}_{i,t}$ represents the closing stock of breeding cows (*i*) in year *t*, $z^{j}_{i,t}$ represents exogenous variables that affect the number of slaughtered cattle *i*, and *V* is a vector exogenous variables that can affect the number of cattle slaughtered.

The average slaughter weight of cattle (*i*) is expressed as follows:

$$slw_{i,t} = f\left(slw_{i,t-1}, p_{i,t}, z_{i,t}^{j}, V\right) \qquad i = 1, \dots, n \;\; j = 1, \dots, m \quad (5),$$

where $slw_{i,t}$ represents the average slaughter weight of cattle *i* in year *t*, $p_{i,t}$ is the real price of beef *i* in year *t*, $z_{i,t}^{j}$ represents the exogenous variables that affect the average slaughter weight *j*, and *V* is a vector of exogenous variables that can also affect the average slaughter weight of cattle.

Demand is modelled through the total domestic consumption of beef, and is determined by the consumption of beef per capita and the product of the total number of consumers, which represents an exogenous variable in the model.

The equation of beef consumption per capita can be expressed as follows:

$$upc_{i,t} = f\left(upc_{i,t}, p_{i,t}, p_{k,t}, gdpc_t, V\right) \qquad k, i = 1, \dots, n; \quad k \neq i \qquad (6),$$

$upc_{i,t}$ is beef and veal meat consumption *i* per capita in the current year *t*, $gdpc_t$ represents real income per capita in the current year *t*, and *V* is a vector of other exogenous variables that can affect consumption.

The equations of import (Im) and export (Ex) can be shown as follows:

$$Im_{i,t}^{k} = f(PR_{i,t}^{k}, DU_{i,t}^{k}, Im_{i,t-1}^{k}) \qquad (7)$$

$$Ex_{i,t}^{k} = f(PR_{i,t}^{k}, DU_{i,t}^{k}, Ex_{i,t-1}^{k}) \qquad (8),$$

Where import $Im_{i,t}^{k}$ and export $Ex_{i,t}^{k}$ of the beef and veal meat *i* in year *t* are expressed through $PR_{i,t}^{k}$ i $DU_{i,t}^{k}$, which represent production and consumption of beef and veal meat *i* and in year *t*.

A set of exogenous data related to the Croatian CAP Strategic plan, i.e., envelope for direct payments, were recalculated and included as an addition to the producer price according to the harmonized approach, forming a reaction price (Salputra et al., 2011). The modeling approach takes into account the different effects of tied and untied payments through multipliers that represent the share of individual aids in the reaction price. Since coupled supports have a stronger impact on the production of a particular market, the multiplier is set at 1.0, while for uncoupled supports it is 0.3 (OECD 2006).

An example of the final appearance of the general equation, in which direct payments are added to the price, thus making the reaction price, looks like this:

$$cct_{i,t} = f\left(cct_{i,t-1}, (p_{i,t} + prc_{i,t}), V\right) \qquad i = 1, \dots, n \qquad (9).$$

The simulation of the development of the beef meat market in Croatia was modeled according to the baseline scenario. The baseline scenario assumes the continuation of the current instruments and measures of the CAP (2023-2027) and stable climatic conditions, without major market shocks (general economic environment, diseases, etc.), with a stable demand trend until 2030.

RESULTS AND DISCUSSION

The AGMEMOD baseline simulation results suggest a continued downward trend from 2023 onwards in domestic beef and veal production, which is simulated to fall from 38.4 thousand tonnes in 2023 to just 30.1 thousand tonnes by 2030 marking a 37% decline compared to 2013 levels. Despite this decline in production, domestic consumption is expected to gradually increase, reaching 64.6 thousand tonnes by 2030, similar to the peak consumption levels observed in 2017 and 2019. Consequently, imports are projected to rise steadily, surpassing 52 thousand tonnes by the end of the projection period. The trade balance, which turned slightly negative again in 2023, is expected to deteriorate further, with net imports reaching 19.2 thousand tonnes by 2030 (Figure1).

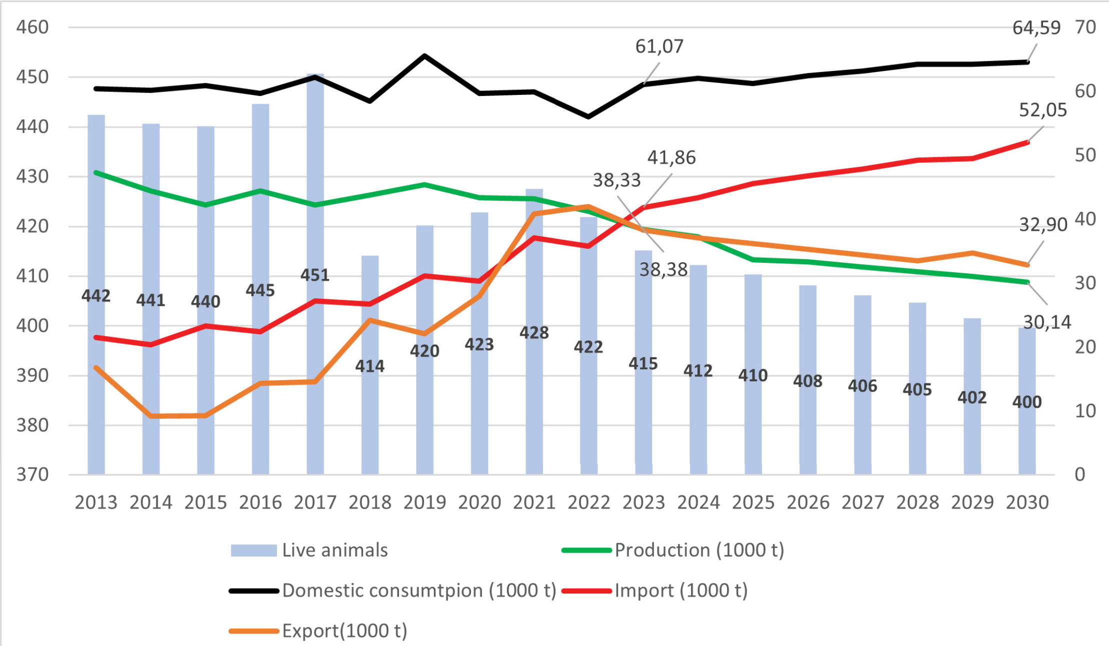

Figure 1. Beef & veal market baseline simulation in the Republic of Croatia up to 2030.

Source: AGMEMOD modelling results

As a result, the self-sufficiency rate is projected to decline from 60% in 2023 to 52% by 2030, reinforcing the trend of growing dependence on foreign supply observed over the past decade (Figure2).

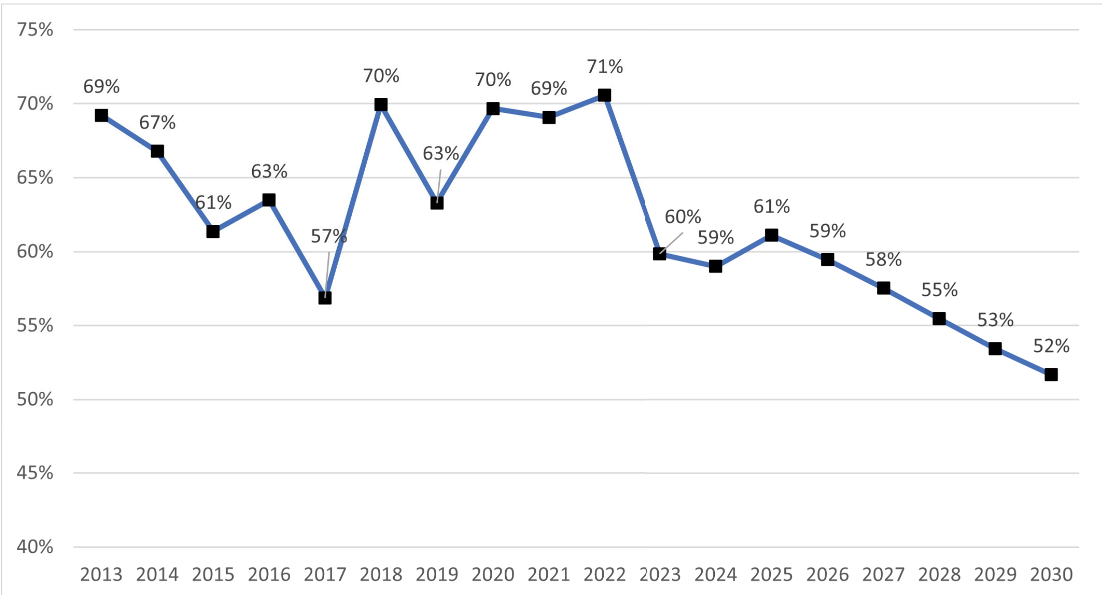

Figure 2. Baseline simulation for self-sufficiency ratio within beef & veal meat market in Croatia up to 2030.

Source: AGMEMOD modelling results

CONCLUSIONS

The AGMEMOD partial equilibrium model has proven to be a suitable analytical tool for simulating baseline outlook of the Croatian beef and veal market, offering insights into potential future developments based on available data and policy assumptions. However, several limitations inherent to models of this type must be acknowledged.

First and foremost, the accuracy of the simulation outcomes is directly linked to the quality of input data, primarily sourced from the Croatian Bureau of Statistics. These data can sometimes be incomplete or imprecise, which may reduce the reliability of the model results. Additionally, AGMEMOD and similar models are not designed to incorporate rural development support measures into their simulations. This is a significant limitation, as such measures can have a substantial impact on production decisions, farm income, and long-term structural change in the sector.

Moreover, the model does not fully capture the volatile nature of agricultural markets. External shocks such as extreme weather events, sudden price collapses, outbreaks of livestock diseases, or geopolitical disruptions are difficult to integrate into a deterministic modelling framework. As a result, the projections should be interpreted with caution, especially over the longer term.

Future improvements to the model should focus on integrating rural development support and adopting a more stochastic or risk-based simulation approach. This would enhance the model's capacity to reflect the real-world uncertainties and complexities of agricultural production and trade.

ACKNOWLEDGEMENT

The paper presents the results of the project CroRIS ID 9849 "Sophisticated agro-economic tools as basis for applied research in the monitoring of the agricultural sector with regard to the specific objectives of the Common Agricultural Policy" supported by the Faculty of Agrobiotechnical Sciences Osijek.

REFERENCES

Chantreuil, F., Hanrahan, K. and van Leeuwen, M. (eds) (2012). The future of EU agricultural markets by AGMEMOD. Dordrecht: Springer

Croatian Bureau of Statistics (2025). Livestock production data. https://web.dzs.hr/PXWeb/Menu.aspx?px_language=hr&px_type=PX&px_db=Poljoprivreda%2c+lov%2c+%u0161umarstvo+i+ribarstvo

Erjavec, E., Donnellan, T. and Kavcic, S. (2006). Outlook for CEEC agricultural market after EU accession. Eastern. European Economics 44(1): 83–103.

Grgić, I., Krznar, S. and Bratić, V. (2019). Poljoprivredna proizvodnja Republike Hrvatske prije i nakon pristupanja EU. Aktualni zadaci mehanizacije poljoprivrede. Zagreb: Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, 487-496.

Kranjac, D., Zmaić, K., Sudarić, T., Ravlić, M., Sušac, M. Z., Grgić, I. and Erjavec, E. (2021). Production and trade impacts of CAP post 2022 reform on main Croatian crop and livestock markets partial equilibrium modelling approach. Agronomy 11(12): 2518.

OECD (2006). Decoupling: Policy Implications, OECD, Paris.

Salamon, P., Banse, M., Donnellan, T., Haß, M., Jongeneel, R. A., Laquai, V., van Leeuwen M., Ioanna, R., Salputra, G. and Zirngibl, M. E. (2019). AGMEMOD outlook for agricultural and food markets in EU member states 2018-2030 (No. 114). Thünen Working Paper.

Salputra, G., Chantreuil, F., Hanrahan, K., Donnellan, T., van Leeuwen, M. and Erjavec, E. (2011). Policy harmonized approach for the EU agricultural sector modelling. Agricultural and Food Science 20: 119–130.

Designing Circular Business Models in Agriculture with Triple-Layer Business Model Canvas – Application on Cascading Use of Apple Pomace

Kristjan Krt, Matej Fatur, Stane Kavčič and Luka Juvančič

Biotechnical faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia, (luka.juvancic@bf.uni-lj.si)

ABSTRACT

This paper explores how the Triple-Layer Business Model Canvas (TLBMC) model supports the development of circular business models from agri-food by-products, using the valorisation of apple pomace as a case study. Technologically, processing of apple pomace is a two-step cascading process with the extraction of pectin and preparation of gelling sugar, while the residues are repurposed into specialty papers. Describing these two circular products along the attributes of TLBMC provides a structured way to capture not just the economic aspects of the products, but also its environmental and social impacts, such as reduced waste, enhanced local supply chains, and new market opportunities. From a purely cost-effectiveness perspective, both products lag behind their conventionally produced counterparts. However, disclosing environmental and social benefits brings new value propositions that can be effectively integrated into the business model, whose competitive advantage builds on sustainable and circular design. In this specific case, gelling sugar rounds off the product portfolio, while paper packaging made from residues clearly highlights the circularity of the portfolio to sustainability-conscious consumers.

INTRODUCTION

Circular products from agri-food by-products offer economic gains by reducing waste disposal costs and creating new revenue streams. Environmentally, they lower resource use and emissions, promoting sustainability. Socially, they support rural economies and job creation. These benefits enhance efficiency and innovation, enabling producers to offer differentiated, eco-friendly products. This can translate into a comparative advantage by lowering production costs, meeting consumer demand for sustainability, and complying with green regulations positioning producers more competitively on the market.

To fully realize the value of circular biobased products, it is essential to communicate their benefits clearly across the entire supply chain from producers and processors to retailers and final consumers. Building awareness and trust among these actors enhances market acceptance and encourages collaboration. Triple-Layer Business Model Canvas (TLBMC) supports this process by integrating economic, environmental, and social value creation into business planning. It helps identify key stakeholders, value propositions, and communication strategies, making the circular benefits visible and tangible throughout the chain. This fosters alignment, strengthens market positioning, and drives the successful adoption of circular innovations.

This paper illustrates how TLBMC can be applied to support the development of a viable business model from a technological prototype based on the cascading use of agricultural by-products (Joyce & Paquin, 2016). By aligning technological innovation with market needs and sustainability goals, the TLBMC serves as a practical tool to guide the transition from concept to commercialization. The approach is demonstrated through the case of apple pomace valorisation a common agri-food by-product highlighting how its transformation into value-added products can create economic, environmental, and social benefits while forming the basis for a circular, market-ready business model.

MATERIAL AND METHODS

This paper is focusing on the process of translating technological prototypes of agricultural by-product recovery into working business models. In doing so, we follow the principle that business models can be applied as supplementary activities on farms, or small-scale processing operations in rural areas. The selection of prospective raw material sources (apple pomace as a side-product of apple processing) and technology prototypes (two-stage cascading use with extraction of bioactive compounds in the first step and recovery of residues with sufficient cellulose content into paper were designed in a previous study. While the characterization of biomass and technological assumptions of the prototypes are described in greater detail in Bolka et al. (2024), their main features are briefly presented below. In cooperation with the developers of the technological prototypes, we translated the proposed technological solutions into a business model, which describes the organisation of the business process, the technological parameters of production, and the form of the economic entity.

Stage 1: Extraction of pectin, sales of pectinated sugar

The prototype envisaged extraction of (technologically and investment proof) pectin from apple pomace (side product from apple pressing). Pectin has many commercially attractive features, including thickening (gelling) and stabilising, which are widely used in the food industry. The final product would not be pectin as such but blended into gelling sugar.

The intended form of the economic operator is a complementary activity of a farm engaged in apple production or processing, or as a specialised micro-processing unit with a processing capacity 30 tonnes of apple pomace per year. Most of the product would probably be sold in the form of direct sales to the final consumers, replacing commercial preparations for gelling homemade fruit preparations.

Stage 2: Special paper products from residual apple pomace

In the second stage, the residues from the extraction process, which contain a considerable share of cellulose (30 per cent) can be used in the production of sustainable paper. The choice of raw material is not ideal in terms of technological characteristics, nor in terms of cost-effectiveness. In fact, the blend for paper production must be supplemented with wood cellulose fibres in order to meet the technological characteristics for the most common types of use (packaging materials, printed matter).

The paper would be produced as a service by a specialised manufacturer of niche paper products in small batch quantities, already present on the Slovenian market (Lavtižar, 2021). The batch required to make it viable to run a paper machine is around 1 tonne of input raw material from which 1 tonne of paper would be obtained. The primary use of this type of paper would therefore be for sustainable packaging and/or printed materials, promoting circular value chains.

In the next step, we also verified the technological and organizational assumptions of the business model by analyzing the costs and benefits. To this end, we have incorporated associated investments, inputs and technological assumptions into the model for calculating unit costs of the two circular products (gelling sugar and paper) and into the model for assessing the economic viability of the investment. A more detailed description of the approach and calculations are beyond the scope of this study. interested readers are referred to a more detailed overview of the methodology in Fatur et al. (2025). In this paper, we only present the results of these calculations, which provide a quantitative insight into the feasibility of investments and the cost-effectiveness of production.

RESULTS

Extraction of pectin and its incorporation into gelling sugar is the sole part of the valorisation cascade of apple pomace which can be which can be technologically and organizationally integrated into the existing apple preparation and processing plant. For this reason, the description of the TLBMC is focusing solely on this part.

TLBMC - economic performance

The economic layer of the business model canvas revolves around the main section of competitive advantage, in this case a new way of obtaining functional ingredients for food products. Such a sustainable product promotes the circular economy and the mobilisation of secondary products, and through it the company aims to inform customers and partners about the new way of obtaining such substances and to build a community with them that appreciates the value of such a product. The activities include the collection of the secondary products of production, their pre-treatment and then their transport to the processing plant where the entire technological process takes place. In our case, this would be on the farm itself. The main input for extraction is the pectin-rich by-products of apple pomace. We intend to generate revenue mainly by adding market value to the product, which brings additional income to the farmer or entrepreneur and significantly reduces the costs of handling the waste (secondary raw material). Key partners are farms and other small producers of the input. Customers can be segmented into two groups: B2C, i.e. selling our products directly to customers (gelling sugar for domestic use), or B2B, i.e. selling the products to companies engaged in similar marketing activities, mainly in the food industry.

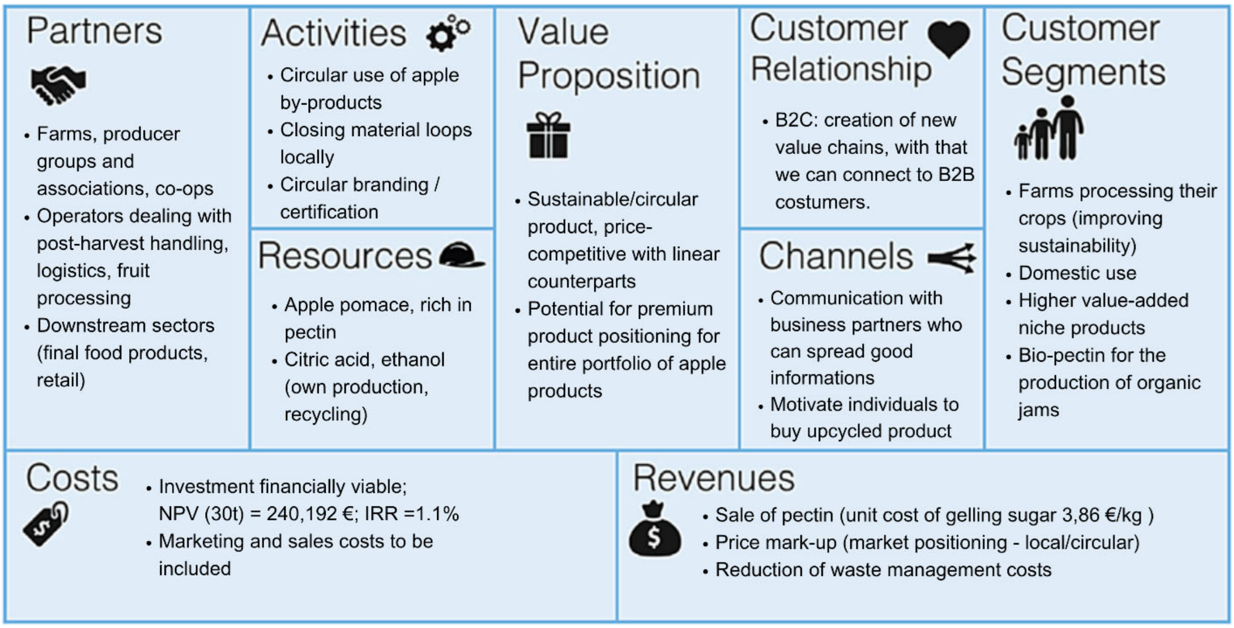

Figure 1. The economic layer of the triple layered business model canvas, associated with pectin extraction from apple pomace

TLBMC – environmental sustainability

The activities cover everything from transport to extraction processes, further handling of the product, then the pectin production process and finally blending into the final product, gelling sugar. In this layer, the focus is on activities that have a greater impact on the environment. For by-product raw materials and activities, we can identify all energy inputs, which may be own or purchased/imported, and the water needed for the operation of the industrial plant. This component also includes all the necessary machinery and plant. In the distribution component, attention is also paid to storage. This is to ensure that the transport are as short as possible. In the case of extracts obtained from secondary products, the use phase is the most important factor in determining the use to which our products will be put. In some cases, this may be a purely domestic use, which occurs through sales in retail outlets (e.g. using gelling sugar for the domestic processing of fruit into products for the winter market), or it may be the sale of our product to smaller companies involved in fruit processing, while being mindful of the ecological and sustainability aspect. The main environmental impact of extraction operations is from production residues, i.e. process water and waste ethanol (about 25%) and solid residues. In the case of pectin extraction from agricultural by-products, one of the main advantages is that it mobilises a raw material that is generally considered as waste. In addition, the extraction residues, which are rich in cellulose, can also serve as an excellent feedstock for the production of sustainable paper, which will be described in the next section.

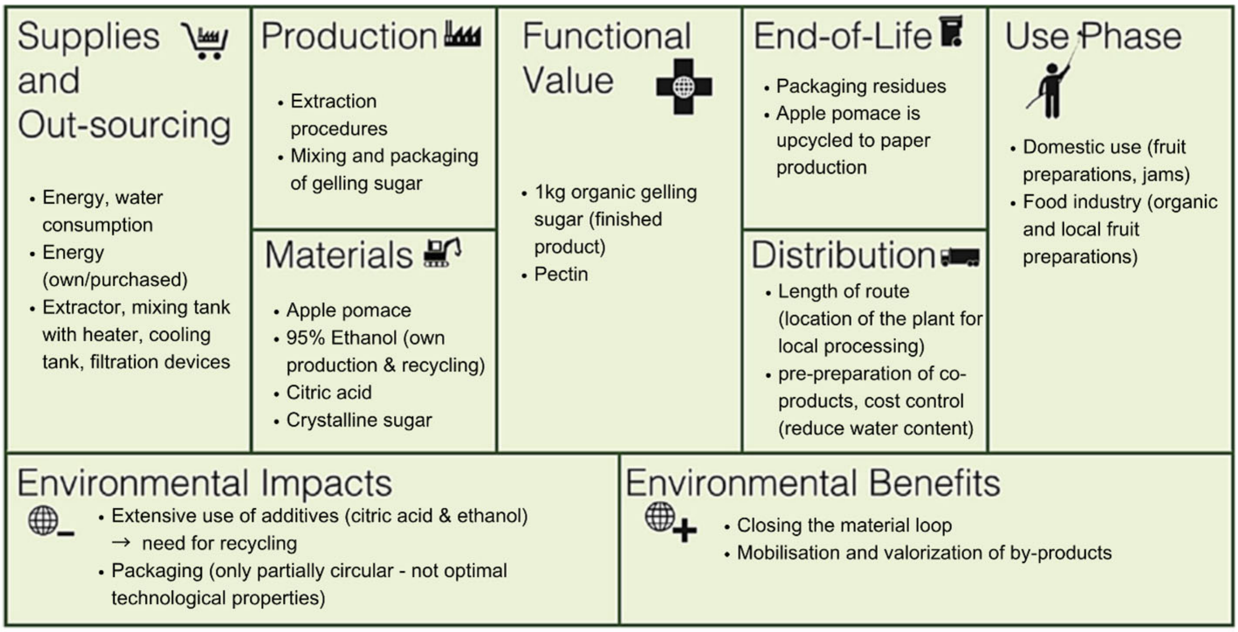

Figure 2. The environmental layer of the triple layered business model canvas, associated with pectin extraction from apple pomace

TLBMC – social aspects of sustainability

One of the main social values is that the end users of the product are in many cases also the suppliers of the input raw material. In this way, long-term cooperation within the environment is strengthened. In our business model, we can refer to all the producers as employees who cooperate with each other within the local environment and thus build a successful business story. Each local environment has to be treated separately by the organisation, with different interests, characteristics and cultures. For companies that operate exclusively at local level, suppliers are of great importance, as they are also part of the local environment and are therefore strongly influenced by the organisation's activities. There are associations that are organised at local level (e.g. Dobrote Dolenjske) or associations of companies/organisations within a single sector (e.g. Bio s kmetij). The company will also be tasked with motivating customers to choose sustainable products and thus support local businesses.

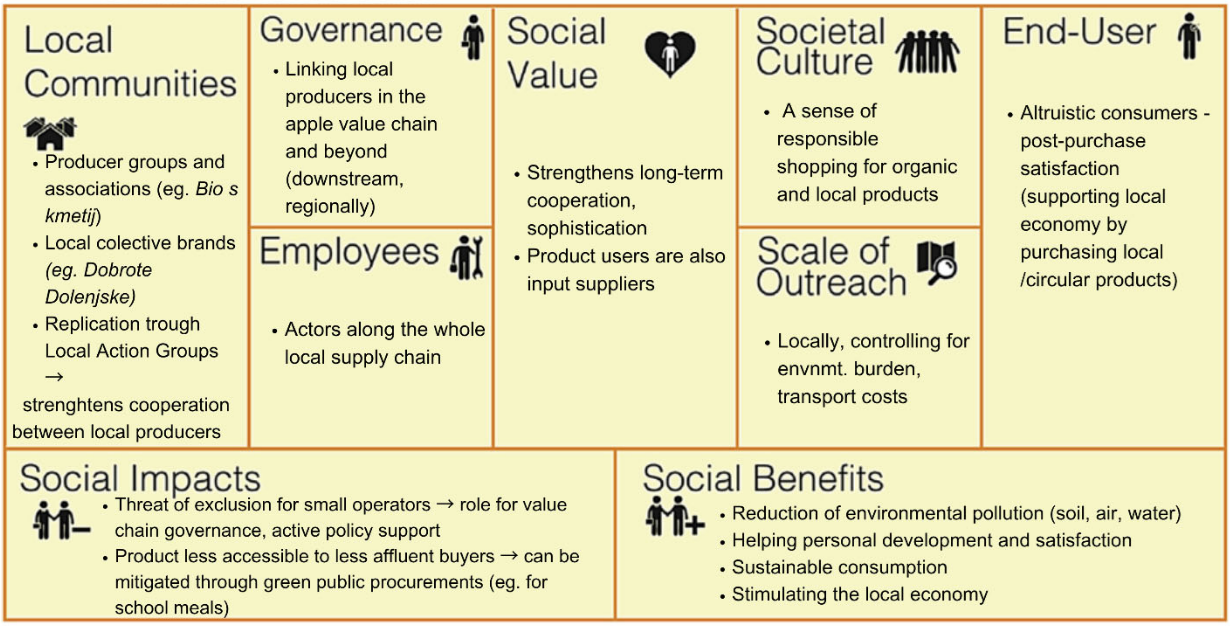

Figure 3. The layer of the triple layered business model canvas, associated with social sustainability of the pectin extraction from apple pomace

The location of the plant has been determined by mapping the locations where most of the feedstock of interest is produced. The end-user, when consuming the product, feels a sense of belonging to local processing, sustainable products and support for the small producer. An important impact on society is that the business model is not the most suitable for small producers, who are excluded because of their small size. In addition, the product is less suitable for socially disadvantaged buyers, who therefore find it harder to afford.

DISCUSSION

The findings of this study shows that a business model based on cascading use of apple by-products brings economic opportunities, and benefits in terms of environmental and social sustainability. However, both products, deriving from this cascade (pectinated sugar and special papers) are dealing also with challenges.

Extraction of pectin and production of pectinated sugar can be defined as a rather attractive entrepreneurial venture. One challenge, which seems quite important to address, is the technology itself, which is intensive on ethanol use, with associated costs and environmental pressure. A possible solution to this problem is the continuous production and recycling of ethanol. Another challenge is price-competitiveness of the product. The own price of (2%) pectinated sugar is 5,1€. This price is only achievable if the product is sold as a premium product (together with other fruit products of the farm / fruit processor in direct sales). Socially, the business model encourages local community, fruit processors and farmers to enhanced corporate responsibility, and improved food system resilience by transforming a waste stream into a valuable resource. The model not only addresses sustainability goals but also contributes to the circular economy and local food security.

On the other hand, sustainable paper is a more environmentally and socially oriented business model. It addresses challenge to use other inputs to produce paper, rather than just conventional way of using wood cellulose. Economically, special papers are not a cost-efficient solution. Relatively expensive paper products (price about 12 EUR per kg). The use of relatively expensive paper products is therefore limited to promotional purposes (e.g. labelling and packaging of premium branded products).

CONCLUSIONS

The paper reveals that cascading use of by-products from agricultural production (in our case horticulture, more precisely apple pomace) can lead to economically feasible and sustainable way of for upcycling. Furthermore, designing and evaluating business models with Triple Layered Business Canvas can reveal less obvious comparative advantages, linked environmental and social sustainability. The approach unveils environmental advantages, including substantial reductions in measurable greenhouse gas emissions and resource use, while also offering new marketing opportunities food producers and farmers. Socially, the model strengthens local communities to create strong supply chains and new employment opportunities, contributing to greater food system resilience. It helps food producer and farmers to position themselves as sustainable companies and their products as premium products. In this respect, development of circular business models using TLBC approach can contribute to more sustainable production and consumption decisions.

ACKNOWLEDGEMENT

The paper draws from the project “Circular technological concepts and business models in Slovenian agriculture”, grant V4-2208, co-funded by Slovenian Research and Innovation Agency and Ministry of Agriculture, Forestry and Food.

REFERENCES

Bolka, S., Fatur, M., Juvančič, L., Kavčič, S., Krt, K., Makovšek, K., Mihelič, R., Osojnik Črnivec, G.I., Schwarzmann, A., Sežun, M., Stojilković, B. and Šutar, N. (2024). Predstavitev prototipov valorizacije stranskih proizvodov kmetijske proizvodnje. Fazno poročilo, Krožne tehnološke zasnove in poslovni modeli v slovenskem kmetijstvu (angl. Circular technological concepts and business models in Slovenian agriculture), V4-2208, Slovenian Research and Innovation Agency, Ljubljana, 87 pp.

Fatur, M., Bolka, S., Fatur, M., Kavčič, S., Krt, K., Makovšek, K., Mihelič, R., Osojnik Črnivec, G.I., Schwarzmann, A., Sežun, M., Stojilković, B., Šutar, N. and Juvančič, L. (2025). Prototipi valorizacije stranskih proizvodov v kmetijstvu: zasnove poslovnih modelov, presoja ekonomske upravičenosti in ocena okoljske trajnosti. Fazno poročilo, Krožne tehnološke zasnove in poslovni modeli v slovenskem kmetijstvu (angl. Circular technological concepts and business models in Slovenian agriculture), V4-2208, Slovenian Research and Innovation Agency, Ljubljana, 110 pp.

Joyce, A. and Paquin, R. L. (2016). The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production 135: 1474-1486.

Lavtižar, V., Kos, I., Košir, L.G., Bavcon Kralj M. and Trebše P. (2021). A Transition Towards the Circular Economy in Slovenia. In Circular Economy: Recent Trends in Global Perspective (pp. 425-456). Singapore: Springer Nature Singapore.

Muscat, A., de Olde, E.M., Ripoll-Bosch, R. et al. (2021). Principles, drivers and opportunities of a circular bioeconomy. Nture Food 2: 561–566.

Osterwalder, A. and Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers (Vol. 1). John Wiley & Sons.

Adoption of Blockchain Technology for Traceability of PGI Lika Potatoes: A Qualitative Study of Stakeholder Perceptions

Željka Mesić[1], Darija Borović[1], Marina Tomić Maksan[1], Marija Cerjak[1], Katarina Sekulić[2], Nikola Vidaković[2], Ana Marušić Lisac[3] and Dragana Milosavljević[3]

[1] University of Zagreb Faculty of Agriculture, Department of Marketing and Innovation in Agribusiness (zmesic@agr.hr)

[2] Lika Potato Producers Association, Senjska ulica 16, Gospić, Croatia

[3] Biotechnicon poduzetnički centar d.o.o., Ul. Hrvatskih iseljenika 30, 21000 Split, Croatia

ABSTRACT

This study explores the readiness, perceptions, and challenges of stakeholders involved in the supply chain of PGI Lika potatoes in adopting blockchain technology. Three qualitative interviews were conducted with a producer, a certification body, and a producer association. The results show that stakeholders recognize the high potential of blockchain for enhancing traceability, trust, and product authenticity. Key barriers include limited digital literacy among producers, insufficient technical support, and inconsistent infrastructure. The study emphasizes the need for targeted education, institutional support, and regulatory alignment to facilitate adoption.

INTRODUCTION

In recent years, blockchain has emerged as a transformative Industry 4.0 technology capable of improving transparency, accountability, and traceability across agri-food supply chains (Treiblmaier, 2018; Casino et al., 2019). This decentralized ledger system allows for secure, tamper-resistant recording of transactions that can significantly enhance data integrity and food safety compliance (Zhang et al., 2020). In the context of PGI-labelled products like Lika potatoes, ensuring product origin and authenticity is critical not only for regulatory compliance but also for maintaining consumer trust and market value. Blockchain, along with other digital tools such as the Internet of Things (IoT), Artificial Intelligence (AI), and Enterprise Resource Planning (ERP) systems, provides the infrastructure needed to track every stage of the production and distribution process in real time. Against this backdrop, the present study conducted within the Horizon ALLIANCE project aims to understand how stakeholders perceive and approach the adoption of blockchain in the PGI Lika potatoes supply chain.

MATERIAL AND METHODS

A qualitative approach was used, based on semi-structured interviews with three stakeholders in the Lika potato supply chain: one producer (SME), one representative of a producer association, and one certification body. The interview guide followed a structured thematic framework covering awareness of 4.0 technologies, perceived usefulness of blockchain, adoption challenges, social influence, institutional support, and intention to adopt. The data were analysed using thematic analysis to identify common patterns and specific concerns.

RESULTS

The results of the qualitative interviews highlight three key areas related to blockchain adoption for PGI Lika potatoes: perceived benefits, barriers to adoption, and contextual influences such as consumer awareness and regulatory expectations.

1. Perceived benefits and value of blockchain technology

The findings from the Lika PGI potato supply chain align closely with global research highlighting blockchain's potential in agri-food systems. Similar to studies by Galvez et al. (2018) and Tian (2016), stake-holders in this case see blockchain as a valuable tool for enhancing traceability, reducing fraud, and increasing trust. The producer emphasized: "*Blockchain is the future of any product... It helps us track production from field to warehouse, and later through the lot number.*" positions.

The certification body highlighted the ability of blockchain to provide timely and accurate data across the supply chain: "*It increases data availability in real time," they noted. However, they also raised concerns about technical feasibility, adding that "incorrect data entry or failure to enter data due to poor internet connection may raise red flags for fraud.*" This demonstrates that while blockchain offers technological advantages, its effectiveness depends heavily on supporting systems and digital infrastructure.

According to the producer association, blockchain has a social governance function: "*Blockchain ensures greater order among producers, as all actors can see and control each other's data entries,*" indicating the importance of transparency and mutual accountability within producer groups.

2. Barriers to adoption of blockchain technology

Despite the positive outlook, all interviewees identified several critical barriers. A recurring theme is the low digital literacy among older producers. The producer association noted: "*Producers are mostly over 60 years old and maintain paper-based records. It would be very difficult for them to independently adopt blockchain technology.*" The producer added that administrative burdens are already significant and proposed a practical solution: "*Producer groups or cooperatives should manage the digital data input for smaller producers.*"This suggests that while the technology may be effective, its usability and long-term success depend on organizational adaptations and support structures. All three agreed that without external assistance especially in technical and administrative domains broad adoption remains unlikely. These challenges aging producers, digital illiteracy, and high administrative load are in line with findings across traditional EU farming regions. In Greece, for example, older farmers resisted digital tools unless supported by intermediaries like cooperatives (Manikas et al., 2022).

3. Consumer understanding and demand

Participants agreed that consumer knowledge of blockchain is currently low. The producer stated: "*Consumers still don't know what blockchain is, but once informed, they will likely appreciate its benefits.*" Similarly, the certification body emphasized that consumer trust and willingness to pay a premium would likely increase with greater transparency: "*Greater transparency would increase trust among consumers and strengthen the product's market value.*" . According to surveys by PwC and IBM, most consumers are not familiar with blockchain, but express stronger trust and willingness to pay more when products are linked to transparent traceability systems.

4. Need for education and coordinated support

All three stakeholders stressed the need for targeted education and coordinated support mechanisms. The producer summarized this aspiration clearly: "We would like to reach the point of adopting blockchain; it would provide added protection and reinforce the authenticity of PGI Lika potatoes."

The collective perspective suggests that blockchain should not be introduced as a standalone solution, but as part of a broader strategy that includes institutional collaboration, consumer education, and organizational reform within the supply chain.

CONCLUSIONS

In summary, this study reveals a strong and genuine interest among stakeholders in adopting blockchain technology to enhance the traceability of PGI Lika potatoes. While the benefits are clearly acknowledged ranging from increased transparency, streamlined data management, reduced administrative burden, to greater consumer trust the road to implementation is met with substantial practical and structural challenges. The low level of digital literacy, particularly among older producers, and the absence of integrated digital systems, highlight the importance of designing adoption strategies that are inclusive, pragmatic, and tailored to local needs.

Blockchain adoption in agri-food systems should not be framed solely as a technological challenge, but also as a socio-organizational transformation. Stakeholders pointed out that cooperatives or producer groups can and should play a central role in supporting the transition by assuming responsibility for data entry and management, thereby relieving producers of complex tasks. Furthermore, certification bodies and regulatory institutions should act as enablers of change by offering targeted support and clear guidelines for blockchain integration into existing traceability systems.

Strategically, blockchain offers a unique opportunity for PGI products to strengthen their identity and defend against market misrepresentation. Its adoption should be perceived as an investment in the long-term credibility, quality assurance, and international competitiveness of regional agri-food products.

Based on these findings, the following recommendations are proposed:

- Develop hands-on training programs tailored to different user profiles, especially older or less digitally experienced producers.
- Establish regional digital support centers, possibly integrated into producer associations or cooperatives.
- Facilitate public awareness campaigns targeting consumers to raise understanding of the value of blockchain in food traceability.
- Ensure regulatory alignment and promote national and EU-level incentives for blockchain adoption.
- Support pilot projects and demonstrations to build trust and showcase practical benefits of the technology.
- Foster cross-sector collaboration between technology providers, academia, and producers to co-develop sector-specific blockchain solutions.

ACKNOWLEDGEMENT

This short paper is based on research undertaken as part on European Union's ALLIANCE project. "This project has received funding from the European Union's HE research and innovation programme under grant agreement No 101084188. Views and opinions expressed are, however, those of the authors only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for any use that may be made of the information the document contains."

REFERENCES

Casino, F., Dasaklis, T. K. and Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. Telematics and Informatics 36: 55–81.

Galvez, J. F., Mejuto, J. C. and Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. TrAC Trends in Analytical Chemistry 107: 222–232.

Manikas, I., Kourgiantakis, M. and Tsakiridou, E. (2022). Adoption of digital innovations in agriculture: The case of Greek farmers. Agricultural Economics Review 23(1): 24–38.

PwC. (2020). Time for trust: The trillion-dollar reason to rethink blockchain.

Rejeb, A., Rejeb, K., Simske, S. and Treiblmaier, H. (2021). Blockchain technologies in logistics and supply chain management: a bibliometric review. Logistics 5(4): 72.

Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. In 2016 13th International Conference on Service Systems and Service Management (ICSSSM) (pp. 1–6).

Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. Supply Chain Management: An International Journal 23(6): 545–559.

Zhang, R., Xue, R. and Liu, L. (2019). Security and privacy on blockchain. ACM Computing Surveys (CSUR), 52(3), 1–34.

Challenges of Preparing Supply Balance Sheet for Game Meat

Ben Moljk and Sara Bele

Kmetijski inštitut Slovenije, Hacquetova ulica 17, Ljubljana, Slovenia, (ben.moljk@kis.si)

ABSTRACT

Slovenia is internationally recognized as a country with a great diversity of wildlife and sustainable game management. Despite very accurate recording of game management, there is no detailed overview of the international trade in game meat and its availability on the Slovenian market. In this paper, we reviewed the available data-bases in the field of game meat and analysed the possibilities of calculating supply balance sheets. The Lisjak (Hunting Association of Slovenia) and OSLIS (Forestry Institute of Slovenia) data systems enable very precise tracking of game handling up to sale by 411 hunting clubs and 8 State hunting reserves. In 2024, 1,524 tons of game were placed on the market in Slovenia, of which the largest share was red deer meat (38.6%) and wild boar meat (36.2%). In 2024, 1,927 tons of game meat were imported into Slovenia, most of which came from Spain and Hungary. 1,470 tons of game meat were exported, a third of which went to Switzerland. The greatest deficiency in the availability of data for calculating supply balance sheet is evident in data on stocks and international trade in game. The data are not shown separately at the level of different types of meat and products, which would allow calculations to be made to the total equivalent of game carcasses using meat loan coefficients.

INTRODUCTION

One of the challenges of the modern world is finding a balance between ensuring food security for a rapidly growing human population and preserving natural resources for food production. Due to numerous pressures on the environment and climate change, the challenge is even more difficult. Agriculture plays a key role in providing food for the population, which is why this sector receives the most attention, including in Slovenia. However, other food sources, such as hunting, fishing and gathering, are rarely mentioned in many discussions and strategic documents.

According to data from the Forest Service of the Republic of Slovenia, the amount of game meat produced in Slovenia exceeds the amount of fish and other aquatic organisms (Zeleno poročilo za leto 2023, 2024), so it would be right to pay more attention to this area as a food source.

Game meat is a food with high nutritional value. Compared to domestic animal meat, game stands out primarily for its higher protein and essential amino acid content, and its content of desirable Omega-3 and Omega-6 fatty acids is also significantly higher (Strazdina et al., 2013).

In developing countries, game meat represents a cheap source of high-quality protein (Hoffman and Cawthorn, 2012), while in the developed world it represents a prestigious commodity in many places and fetches unreasonably high prices, which discourages many consumers from consuming game meat more frequently.

Slovenia is recognized as a country with a high diversity of wild forest animals due to its high forest cover (Zeleno poročilo za leto 2023, 2024), forest conservation and diversity of habitat types (ARSO, 2001). It is also recognized as a country with a high level of sustainable management of game and other wild animals that are not considered game (LZS, 2024), where game is a species of wild mammals and birds that are hunted and have a defined hunting season (Zakon o divjadi in lovstvu, 2025).

Consumption and self-sufficiency of the main agricultural products are monitored annually within the framework of the preparation of food balances for individual products (SURS, 2023; EUROSTAT, 2009), while the calculation of supply balance sheets for non-agricultural food sources is not a common practice. The importance of game meat as a source for human food consumption and the need for balance data prompted us to review the state of the obtained game meat and analyse the possibility of preparing a supply balance sheet for game meat in Slovenia.

MATERIAL AND METHODS

The first part of the research included an overview of the collection of data on game poaching by individual game species and the subsequent handling and trade of game meat. We focused on all ungulate game living in Slovenia: red deer, roe deer, chamois, fallow deer, mouflon, alpine ibex and wild boar. We disregarded the breeding of game in pens (red deer and fallow deer), for which, despite the lack of data, we estimate that they are not a significant source of game meat quantities and have therefore been disregarded. We also disregarded the hunted quantities of small and other game (wild hare, pheasant, bear, nutria, badger, dormouse, ...), since this type of game is not traded or the quantities that enter the human food chain are very small.

For the purposes of the analysis, we focused only on data on the quantities of game hunted and sold, regardless of the type of buyer, as only these represent the entry into the human food chain.

We addressed a request to obtain data for 2024 to the Hunting Association of Slovenia (LZS), the Forest Service of the Republic of Slovenia (ZGS), and the Administration for Food Safety, Veterinary and Plant Protection (UVHVVR).

The LZS has the Lisjak data system. In addition to administrative support for hunting ground managers, i.e. hunting clubs, the very extensive data portal includes data on biotechnical operations in hunting grounds, hunted game and game losses. The data recording is very detailed, at the level of age and sex structure of each species. From the perspective of an aggregate review, Lisjak (LZS, 2011) has a drawback, as it does not include data on hunting and game losses in State hunting reserves (LPN), which are under the auspices of the ZGS.

The Forestry Institute of Slovenia (GIS) has a wider database. Their information system OSLIS (2025) combines data from the Lisjak system and LPN data. The purpose of the OSLIS system is to provide information and data support for the preparation of game management plans. OSLIS is intended for public, professional and research use. Tabular, graphic and cartographic displays of data on hunting and losses in game populations in Slovenia are available to the public. The data is presented in the form of summaries for the state and hunting management area (LUO; i.e. hunting areas of several hunting clubs) levels, which is not sufficient for our analysis, so it was necessary to obtain data at the level of reporting units.

In addition to the production, processing or otherwise obtained quantities of food, foreign trade data are also re-quired for the calculating supply balance sheets. These are monitored and published annually by SORS at the level of the 8-digit nomenclature on the publicly accessible SiStat web portal (SURS, 2025). The tariff codes that cover game meat or other game products are: 0281090 - Meat and offal of wild hares, fresh, chilled or frozen, 02089030 - Meat and offal of wild game other than rabbits and hares, fresh, chilled or frozen, 05021000 - Bristles and hair of domestic or wild boars and waste of such bristles, for brush making and 16029031 - Meat products of wild game or domestic rabbits, other edible offal.

For the purposes of calculating supply balance sheet for game meat, data on international trade in game meat is not precise enough due to the combination of data on meat from all types of game and the different stages of meat preparation. We contacted the UVHVVR for help, but apart from records of game processing and skinning plants, they do not have any information. However, they do have information on business entities that carry out international trade in game meat, which allowed us to gain a more detailed insight into this segment of trade.

Part of the game meat is delivered to Slovenia in packaged form through retail chains, so we also asked the Chamber of Commerce of Slovenia (TZS) for more detailed data on the quantities of game meat by type of game and level of packaging.

Table 1. Average lean meat percentages (%) of game at different processing stages (Ficko, 2007)

Type of game	Skinning	Meat section	Deboning	Cutting
Red deer	89,4	82,3	64,2	61,8
Roe deer	84,7	78,2	57,4	54,9
Chamois	92,2	84,7	57,9	57,1
Moufflon	91,6	86,0	59,2	58,0
Wild boar	79,2	75,4	53,0	51,5

Data for game meat in the Lisjak and OSLIS data and information systems refer to game carcasses with skin (without head and hooves, in the case of wild boar also with head), while trade in game meat takes place in the form of carcasses with skin, meat with bones and packaged meat without bones. To calculate the supply balance sheet for game meat, calculations of individual stages of meat processing into a common equivalent are required, and for this, meat leans coefficients (Ficko, 2007) are required at several levels of processing of carcasses and game meat; skinning, meat section, boning and cutting of meat.

RESULTS AND DISCUSSION

Analysis of data from the OSLIS information system showed that hunting clubs and State hunting reserves sold 1,524.3 tons of game (carcasses with skin) in 2024. Of this, 1,308.6 tons were sold by hunting clubs, which represents around 86% of the total amount of game sold. The largest share is red deer meat, namely 38.6%, which amounts to 588.1 tons.

Table 2. Mass (t) and structure (%) of game taken in Slovenia in 2024

Type of game	Weight of cleaned carcasses[a] (t)	Share (%)
Red deer	588,1	38,6
Roe deer	323,4	21,2
Chamois	38,3	2,5
Fallow deer	13,2	0,9
Moufflon	8,6	0,6
Alpine ibex	0,2	0,0
Wild boar	552,4	36,2
Total	1.524,3	100

[a] Cleaned carcasses with skin.

Source: OSLIS (2025)

With 552.4 tonnes (36.2%), the amount of wild boar meat obtained is the second most important type of game meat. A decade ago, the number of wild boars hunted was half that of 2024 (Zeleno poročilo za leto, 2024), and the amount of wild boar meat obtained and placed on the market was less than that of roe deer meat.

Due to the increase in the wild boar population and the decline in the roe deer population, roe deer meat represented the third most important source of game meat. In 2024, 323.4 tons were obtained, representing a good fifth of the game meat sold.

A review of available foreign trade data showed that all game meat, excluding hares and rabbits, is classified under the 8-digit tariff code 02089030, regardless of the level of processing. This makes it impossible to convert quantities to a total mass equivalent, as is the case with comparable beef meat, where the equivalent is a carcass slaughter weight.

Based on foreign trade data, trade in game meat is carried out only between EU Member States and Switzerland. In 2024, trade in game products with third countries took place only with China (import of bristles for industrial purposes) and Serbia (export of meat), and the quantities were at the level of a truck or less. In 2024, 1,927 tons of game meat, game meat products or other game products were brought to Slovenia, with around half a percent representing goods for industrial purposes. Game exports in 2024 amounted to 1,469.9 tons, and practically the entire quantity represented meat for human consumption.

Slovenia imports most game from Hungary, Spain, Slovakia and Poland, which are known to have large numbers of red deer and wild boar and are among the largest suppliers of game meat in Europe (Stoica, 2022). These four countries accounted for 79% of total game imports in Slovenia in 2024.

Slovenia exported the most game meat to Switzerland in 2024, which at 491 tons represented about a third of total exports. In the same year, 39% of game meat was exported to Spain and Italy, and 11% to the Netherlands.

Table 3. Foreign trade of game meat in 2024

Import (t)		Export (t)	
Total	1.927,0	Total	1.469,6
Of this:		Of this:	
meat and offal of game other than rabbits and hares	1.884,1	meat and offal of game other than rabbits and hares	1.455,4
Country		Country	
Spain	438,4	Switzerland	490,8
Hungary	430,3	Spain	288,9
Slovak Republic	340,0	Italy	278,8
Poland	309,9	Netherland	164,6
Netherland	122,3	France	94,4
Other	286,1	Other	152,1

Note: provisional data

Source: SORS (2025)

A parallel review of UVHVVR data showed that only two companies in Slovenia are engaged in the purchase of game, preparation of game meat and wholesale sales game or game meat products. One company only purchases game carcasses and transports them to Italy for processing, while the other company purchases game in Slovenia and EU member states for processing, and the main part of the total sales of game meat for this company is sales on foreign markets.

Part of the trade with game meat also takes place through retail sales in trading systems. Due to the lack of data or lack of public availability of data, it is impossible to estimate the quantities through various marketing channels. For now, the only option left is to obtain data directly from business entities.

CONCLUSIONS

The analysis of the game meat market has shown that the game meat trade in Slovenia is by no means a marginal area. For comparison, in 2023 (the latest available data), 1,411 tons of fish and other marine and freshwater aquatic organisms were obtained in Slovenia, which is less than the game meat obtained in 2024 (1,542 tons).

Apart from the availability of data at the level of hunting and placing on the market and data on international trade in game at the aggregate level, public data systems do not currently have sufficiently detailed data to enable the calculations of supply balance sheet for game meat. For this purpose, it would be necessary to establish reporting of international trade in game meat at the level of different levels of meat processing or processing, i.e. separately at the level of game meat and game meat products, similar to the case of beef or pork, whereby for greater accuracy, due to the different meat leans, it is desirable to record separately by species of ungulate game.

To calculate the supply balance sheet for game meat and ensure full comparability with supply balance sheets for meat of domestic animal, records of stocks of game meat and game meat products are also required. Since this is a normal business data from company balance sheets, the availability of the data should not be questionable.

After establishing a suitable database at the meat and product level, separated by different types of ungulate game, and using lean meat coefficients, it is possible to convert to the total equivalent of game carcasses and calculate the supply balance sheet for game meat.

The problem could arise due to the small number of observed units. The data would acquire confidential status, and further use and display of the data could therefore be limited or prevented.

REFERENCES

ARSO. (2001). Pregled stanja biotske raznovrstnosti in krajinske pestrosti v Sloveniji. Ministrstvo za okolje in prostor Republike Slovenije, Agencija RS za okolje, Ljubljana, p. 244. https://www.gov.si/assets/ministrstva/MNVP/Dokumenti/Narava/stanje_biotske_raznovrstnosti.pdf

Eurostat. (2009). Manual for the compilation of supply balance sheets for meat. Luxembourg, European Commission, Eurostat.

Ficko, A. (2007). Najnižji izplen mesa uplenjene divjadi. Diplomska naloga. Živilska šola Maribor. Višja strokovna šola. Maribor. p. 72.

LZS. (2011). Pravilnik o lovsko informacijskem sistemu Lovske zveze Slovenije. https://clan.lovska-zveza.si/userfiles/Zakonodaja/pdf/Pravilnik_o_lovsko_informacijskem_sistemu.pdf.

LZS. (2025). Lovstvo. https://www.lovska-zveza.si/lovstvo/

OSLIS. – Osrednji Slovenski Lovsko-Informacijski Sistem. http://oslis.gozdis.si

Hoffman, L.C. and Cawthorn, D.M. (2012). What is the role and contribution of meat from wildlife in providing high quality protein for consumption? Researchgate. https://www.researchgate.net/profile/Donna-Maree-Caw-thorn/publication/270084046_What_is_the_role_and_contribution_of_meat_from_wildlife_in_providing_high_quality_protein_for_consumption/links/550ac8960cf2855640955baf/What-is-the-role-and-contribution-of-meat-from-wildlife-in-providing-high-quality-protein-for-consumption.pdf?__cf_chl_tk=aMdLDDedNh_LZRkj_bVs2quIMlIqLDBj.l8FizH.Axw-1747288987-1.0.1.1-stNysTXcJ.0ZWIHCbg6Wt8zutFwe1U82c8F39z5p4vM

SORS. (2023). Bilance proizvodnje in potrošnje kmetijskih proizvodov. Ljubljana, Statistični urad Republike Slovenije. https://www.stat.si/statweb/File/DocSysFile/9744

SORS. (2025). Izvoz in uvoz po 8-mestni šifri Kombinirane nomenklature in po državah, Slovenija, letno (kumulativni podatki). https://pxweb.stat.si/SiStatData/pxweb/sl/Data/-/2490201S.px

Stoica, G. (2022). Analysis of game meat production, Agrarian Economy and Rural Development - Trends and Challenges. International Symposium. 13th Edition, The Research Institute for Agricultural Economy and Rural Development (ICEADR), Bucharest, pp. 155-161. https://www.econstor.eu/bitstream/10419/301719/1/ICEADR-2022-p155.pdf

Strazdiòa, V., Jemeïjanovs, A. and Đterna, V. (2013). Nutrition value of wild animal meat. Proceedings of the Latvian academy of sciences Section B 67(4/5) (685/686): 373–377.

Zakon o divjadi in lovstvu. (2025). Uradni list RS. https://pisrs.si/pregledPredpisa?id=ZAKO3780

Zeleno poročilo za leto 2023. (2024). Travnikar T. (ured.), Bedrač M., Bele S., Bleiweis A., Brečko J., Kožar M., Moljk B., Telič V., Zagorc B. Poročilo o stanju kmetijstva, živilstva, gozdarstva in ribištva v letu 2023. Ljubljana, Kmetijski Inštitut Slovenije.

Understanding Farmers' Intention to Participate in Online Sustainability Training: Insights from Slovenia Using an Extended Theory of Planned Behaviour

Ana Novak, Živa Alif, Luka Juvančič and Tanja Šumrada

Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana, Slovenia, (ana.novak@bf.uni-lj.si)

ABSTRACT

This study explores the factors influencing farmers' intention to participate in sustainability-related agricultural training, with particular attention to the role of online delivery formats. Drawing on the extended Theory of Planned Behaviour (TPB), we analysed survey responses from 4742 Slovenian farmers who attended training in organic farming, animal welfare, or agri-environmental measures. Structural equation modelling was used to assess the predictive value of psychological constructs (attitudes, subjective norms, and perceived behavioural control), along with satisfaction with previous training. In addition, logistic regression examined the determinants of participation in online versus in-person sessions. Results indicate that perceived behavioural control and positive attitudes are key drivers of participation intention, while subjective norms had little influence. Satisfaction with training, particularly with content quality, was also positively associated with intention. Farmers who attended online training reported lower satisfaction compared to those who participated in person. However, online formats were more often chosen by farmers with limited time, mobility, or transport options. These included older, female, and parttime farmers. These findings suggest that while online training can expand access for certain groups of farmers, improvements in training design and delivery are needed to ensure a positive learning experience. Tailoring digital formats to farmers' needs may enhance the effectiveness and inclusiveness of advisory services.

INTRODUCTION

Agriculture is increasingly facing complex challenges stemming from environmental and climate crises, volatile markets, and evolving societal expectations. These challenges demand that farmers enhance their access to up-to-date information and adopt innovative practices to ensure sustainability (Krafft et al., 2022). Agricultural advisory services are key to enabling this transition, as they facilitate the dissemination of new knowledge and practices, including organic farming, agri-environmental measures, and technological innovations (Moojen et al., 2023; Österle et al., 2016; Tamini, 2011; Toma et al., 2018).

In recent years, information and communication technology (ICT) has emerged as a promising channel for delivering agricultural advisory services. ICT can improve the accessibility and personalisation of advice, enhance learning flexibility, and broaden the reach of training programs at a lower cost (Fabregas et al., 2019; Kiiza & Pederson, 2012; Klerkx, 2021; Singh et al., 2018). The relevance of ICT-based advisory support increased during the COVID-19 pandemic, which accelerated the adoption of online training formats (Mathuabirami et al., 2023; Michaelis et al., 2022). While educational studies suggest that online learning may improve accessibility and performance (Joshi et al., 2022; Means et al., 2010), its adoption in agriculture still faces concrete challenges, including uneven internet connectivity in rural areas, limited access to digital equipment, low levels of digital literacy among some farmers, and reduced opportunities for peer interaction and real-time feedback during online sessions (Segbenya et al., 2022; Yang & Yang, 2023). Moreover, farmers are not a homogeneous group; differences in socio-economic background, motivations, and learning preferences shape how they perceive and access training opportunities (Huber et al., 2024; Klerkx, 2022). Therefore, effective design of ICT-based training should consider these diverse needs (Yang & Yang, 2023).

This study explores Slovenian farmers' intention to participate in sustainability-related training, delivered either online or in person, using an extended Theory of Planned Behaviour (Ajzen, 1991). By incorporating satisfaction with previous training into the TPB framework, the study aims to assess the impact of psychological, social, and experiential factors on farmers' willingness to engage in future training and to offer policy-relevant insights for designing inclusive and effective advisory services.

MATERIAL AND METHODS

Theoretical framework and survey design

To investigate farmers' intention to participate in agricultural sustainability training, we developed a structured questionnaire based on the Theory of Planned Behaviour (TPB) (Ajzen, 1991). PB is a widely used model for predicting individual behavioural intentions, which is considered the most immediate predictor of actual behaviour. According to the theory, intention is shaped by three core components: attitude towards the behaviour, subjective norms, and perceived behavioural control (PBC) (Fishbein & Ajzen, 2010). The model has been successfully applied in both education (Hollett et al., 2020; Lung-Guang, 2019) and agriculture (Sok et al., 2021). In the agricultural advisory context, farmers' perceived ease of participating in training (PBC), their own beliefs about training value (attitudes), and the perceived expectations of others (subjective norms) shape their willingness to engage in training sessions (Hall et al., 2019). However, research suggests that TPB's explanatory power can be improved by integrating additional constructs. Satisfaction with previous educational activities has been shown to be a key factor in education (Chiu et al., 2007; Lu et al., 2019) and advisory contexts (Elias et al., 2016; Kassem et al., 2021), reflecting the perceived value of the training concerning invested time and effort (Shahsavar & Sudzina, 2017). Therefore, we extended the TPB framework by including satisfaction with past training as a proximal predictor of future training intention (Figure 1). We conceptualised satisfaction as a second-order construct composed of three dimensions: content quality, lecturer quality, and training design (Garg & Sharma, 2020; Gopal et al., 2021). This extended model allows us to analyse not only psychological and social predictors of farmers' training intentions, but also how their training experiences shape future engagement.

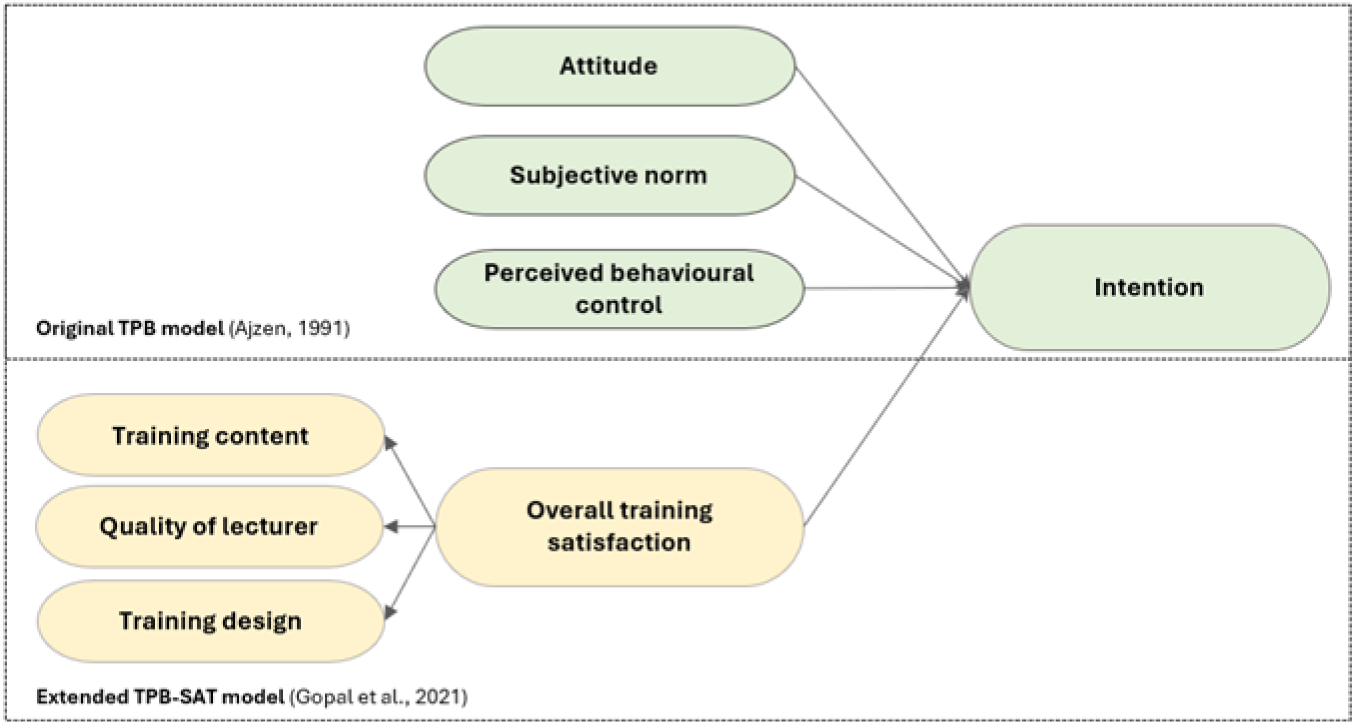

Figure 1. Theoretical research framework based on the extended Theory of Planned Behaviour (TPB).

To operationalise the extended TPB model, we developed survey items based on established measurement instruments from existing studies in agriculture and education. The wording was adapted to the context of Slovenian advisory training, and the initial questionnaire was refined through expert focus groups and pilot testing with 15 farmers and agricultural advisors. The final survey consisted of four sections: (1) informed consent and general purpose; (2) TPB constructs (attitudes, subjective norms, perceived behavioural control, and intention); (3) satisfaction with training (content, lecturer, and training design); and (4) socio-demographic and farm characteristics. For statements regarding TPB and satisfaction constructs, responses were collected on a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree), where respondents indicated their agreement with statements such as 'I can easily participate in training sessions' (PBC) or 'The training content was relevant and useful' (satisfaction).

Data collection and analysis

The survey was conducted between November and December 2021 during annual training programs for farmers participating in CAP measures of Organic Farming (OF), Animal Welfare (AW), and Agri-Environmental-Climate Measures (AECM). These included 5002 surveys submitted following 38 online training sessions across Slovenia and 469 printed forms collected at 16 in-person sessions held in central and eastern regions. Before analysis, we screened the data and excluded any questionnaires with more than 5% missing values or with protest responses (e.g. uniform answering patterns or non-engagement with reversed items).

Descriptive statistics were calculated, and variables with skewed distributions were normalised using Box-Cox transformations. Missing data were imputed using multiple imputation with predictive mean matching (Buuren and Groothuis-Oudshoorn, 2011). To examine the determinants of farmers' intention, we used Structural Equation Modelling (SEM) in R (lavaan and semTools packages; Rosseel, 2012; Jorgensen et al., 2022). We tested three models: the original TPB model, the extended TPB-SAT model including satisfaction, and a further model (TPB-SAT-Setting) that included the training delivery mode (online vs in-person) as an explanatory variable for satisfaction. Model fit was assessed using conventional indices (RMSEA < 0.07, SRMR < 0.08, CFI and TLI > 0.94) (Hair et al., 2013). Additionally, we applied binomial logistic regression to identify factors influencing farmers' participation in online versus in-person training. Lastly, linear mixed-effects models were used to test whether variation in training satisfaction was attributable to training location or delivery mode.

RESULTS

Structural equation modelling results

The original TPB model explained a substantial share of the variance in farmers' intention to participate in future sustainability training ($R^2 = 0.852$). Among the latent variables, perceived behavioural control (PBC) was the most influential predictor ($\beta = 0.766$, $p < 0.001$), followed by attitudes ($\beta = 0.201$, $p < 0.001$). Subjective norms, however, showed no significant effect ($\beta = 0.000$, $p = 0.992$).

The extended TPB-SAT model, which incorporated satisfaction with prior training, modestly improved explanatory power ($R^2 = 0.858$). In contrast to the original TPB model, the model fit indices show a weaker fit to survey data but are still at an acceptable level. In this model, satisfaction had a significant positive effect on intention ($\beta = 0.130$, $p < 0.001$), in addition to PBC ($\beta = 0.705$) and attitudes ($\beta = 0.174$). Satisfaction itself was modelled as a second-order construct comprising three components: training content (loading = 0.942), lecturer quality (0.811), and training design (0.725), confirming their strong contribution to overall training experience.

To explore differences in satisfaction between online and in-person formats, training delivery mode was included as an additional regression term in the TPB-SAT-Setting model (Figure 2). Results revealed a significantly lower satisfaction among farmers who attended online training, concerning training content ($\beta = -0.498$), training design ($\beta = -0.479$), and lecturer quality ($\beta = -0.365$). These differences could not be explained by variation in location or individual trainers, suggesting an inherent limitation of the online format under the existing training design.

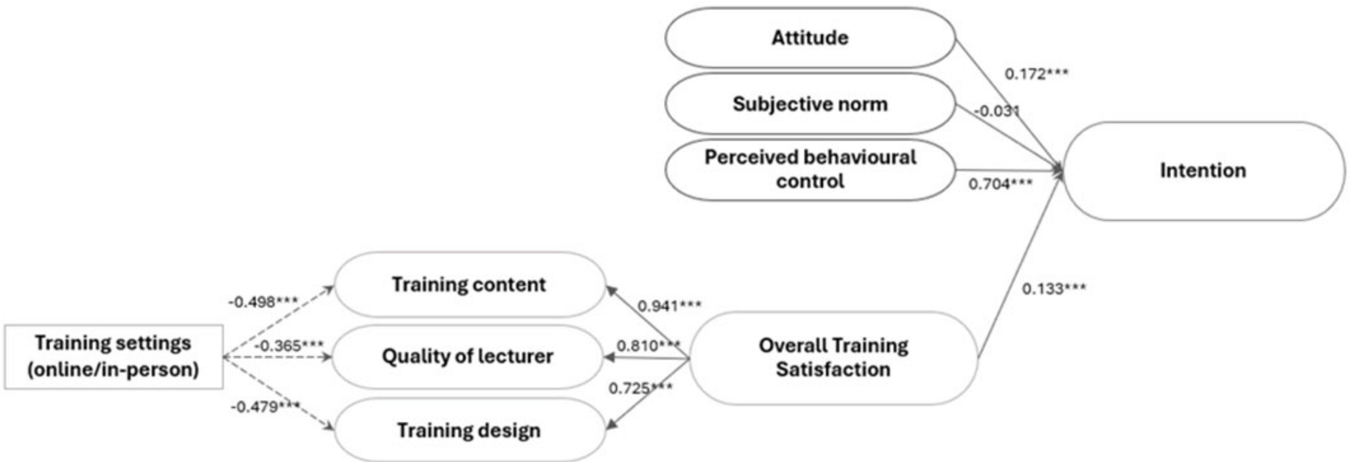

Figure 2. The extended TPB-SAT-Setting structural model with the effect of the mode of training (online or in-person) on the three components of overall training satisfaction.

Logistic regression results

A binomial logistic regression was used to identify factors influencing farmers' choice between online and in-person training formats. The analysis showed that farmers with reliable internet access, ICT equipment, and digital literacy were significantly more likely to choose online training. Online training was also more commonly attended by farmers with limited time or transportation options (Table 1). Moreover, participation in online training was more frequent among older, female, and part-time farmers, as well as those with a lower proportion of household income derived from agriculture. Among the training programs, participants in animal welfare (AW) training were the most likely to attend online sessions, while those in agri-environmental climate measure (AECM) training were more likely to attend in person.

Table 1. Regression model of factors influencing farmers' participation in online or in-person (baseline) training sessions

	Estimate	Std. error	Statistic	P-value
(Intercept)	3.47	0.66	5.27	<0.001
PBC: I have a reliable internet connection, computer equipment, and knowledge to participate in online training.	0.87	0.07	12.09	<0.001
PBC: I can easily participate in training sessions.	-0.43	0.10	-4.45	<0.001
PBC: I can easily arrange transportation if the training takes place in person.	-0.27	0.09	-2.95	0.003
Participation in animal welfare (AW) training	2.50	0.52	4.83	<0.001
Participation in agri-environmental (AECM) training	-0.59	0.15	-4.01	<0.001
Gender – Female	0.57	0.19	3.06	0.002
Age	0.02	0.01	2.49	0.013
% household income from farming	-0.15	0.07	-2.35	0.019
PBC: I find it challenging to make time for participation.	0.14	0.08	1.91	0.056
Farm size	0.00	0.00	1.82	0.069
Production results	-0.22	0.13	-1.70	0.090
Farming experience	-0.43	0.34	-1.27	0.204
Social norms	0.18	0.22	0.81	0.418
Attitudes	0.10	0.21	0.47	0.641
Farm future	0.05	0.11	0.47	0.642
Education	0.04	0.10	0.41	0.680
The economic position of the farm	-0.04	0.12	-0.35	0.727

DISCUSSION

The results of this study provide insights into the factors that influence farmers' willingness to engage in sustainability-related training, particularly in the context of online training formats. The results show that perceived behavioural control (PBC) is the strongest predictor of farmers' intention to participate in training. This is consistent with findings from previous education (Ajzen & Madden, 1986; Hollett et al., 2020) and agriculture studies (Hall et al., 2019; Sok et al., 2021) and suggests that practical considerations, such as time availability, transport, and the ability to organise participation, play an important role in shaping engagement in future training. Attitudes also had a positive effect, indicating that farmers who see value in training are more likely to attend. On the other hand, subjective norms were not significantly associated with intention, aligning with Hollett et al. (2020) and the meta-analytical study by Armitage & Conner (2001), which found that subjective norm typically has a weak predictive power on intention. This could be due to the ex-cathedra format of the training sessions, which offered few opportunities for peer interaction. Furthermore, previous studies suggest that subjective norms tend to exert a stronger influence in contexts involving economic outcomes or technology adoption (Hennessy & Heanue, 2012; Sok et al., 2021), whereas pro-environmental behaviours may be perceived as more individually motivated and less socially pressured (Helferich et al., 2023).

Although the inclusion of overall training satisfaction only moderately improved the model's explanatory power, satisfaction proved to be a significant predictor of future participation, supporting findings from education literature (Chiu et al., 2007; Gopal et al., 2021) and underlining the value of continuous quality monitoring in advisory services. Among the satisfaction components, training content was the strongest predictor, followed by lecturer quality and training design. These results underscore the need to prioritise content relevance, engaging delivery, and well-organised sessions to enhance advisory effectiveness.

One of the most policy-relevant results is the difference in satisfaction between online and in-person training. Farmers attending online sessions consistently reported lower satisfaction with all aspects of the training. Some of this difference may be explained by methodological variation, as paper-based or in-person surveys are known to produce more favourable satisfaction responses compared to online formats (Dillman et al., 2009). However, the disparity could also stem from variations in the learning environments between the two training settings. Several factors may contribute to this difference, including reduced interaction, limited opportunities for feedback, increased cognitive load, and difficulties in maintaining concentration in online learning environments (Mayer, 2017; Means et al., 2010). Among these, dissatisfaction with training content was the most notable, possibly due to insufficient adaptation of materials for digital delivery or a misalignment between the delivery approach and farmers' preferred ways of learning.

Despite lower satisfaction levels, online training was more frequently chosen by farmers facing structural barriers to in-person participation: older age, limited time, lack of transport, and part-time farming status. These groups appear to value the flexibility of online formats, a trend echoed in other ICT-advisory studies (Yang and Yang, 2023; Michaelis et al., 2022). Interestingly, female farmers were also more likely to choose online training, a finding that deserves further investigation, as gendered preferences and responsibilities may shape how farmers engage with learning opportunities. Importantly, the results indicate that digital inequality persists, as online training is more accessible to those with the necessary infrastructure, skills, and confidence. This emphasises the need for investments in rural broadband, ICT equipment, and digital skills training, especially if online advisory services are to be scaled up equitably (Abdulai et al., 2023; Khan et al., 2022). Advisory providers should also consider diversifying their digital formats shorter modules, interactive platforms, and blended learning options may help overcome some of the current shortcomings.

CONCLUSIONS

This study used an extended Theory of Planned Behaviour framework to examine the factors influencing farmers' intention to participate in agricultural sustainability training, with a particular focus on online delivery formats. The results underline the importance of perceived behavioural control and attitudes as key predictors of intention, while subjective norms played a more limited role. In addition to these psychological drivers, the study confirmed that satisfaction with previous training is also associated with future participation, most strongly through perceptions of training content quality, followed by the lecturer quality and the training design. These findings emphasise the importance of delivering advisory services that are not only accessible but also well-structured and engaging.

Despite the lower satisfaction reported among participants in online formats, our findings also point to the potential of online training as a flexible and inclusive knowledge transfer tool. Digital delivery was particularly valuable for farmers facing constraints related to time, mobility, or location. This suggests that, when appropriately designed, online formats can complement traditional methods and extend access to groups who might otherwise be excluded. To fully realise this potential, it is important to move beyond one-size-fits-all approaches and invest in digital pedagogies that respond to farmers' learning preferences and technological capacities.

Furthermore, the results highlight the need for regular evaluation and adaptation of advisory services. Future research could examine how different training formats affect actual behavioural outcomes and long-term knowledge retention. There is also scope to explore the learning needs of different subgroups of farmers to support more targeted and effective training strategies.

ACKNOWLEDGEMENT

This study was supported by the Slovenian Research Agency under grant P4-0022 (B) and the Ministry of Agriculture, Forestry and Food under grant CRP V4-2020. The authors would like to thank the Slovenian public advisory service (Javna služba kmetijskega svetovanja) for their help in data collection.

REFERENCES

Abdulai, A.-R., KC, K. B. and Fraser, E. (2023). What factors influence the likelihood of rural farmer participation in digital agricultural services? Experience from smallholder digitalization in Northern Ghana. Outlook on Agriculture 52(1): 57–66.

Ajzen, I. (1991). The theory of planned behaviour. Organizational Behavior and Human Decision Processes 50(2): 179–211. h

Ajzen, I. and Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. Journal of Experimental Social Psychology 22(5): 453–474.

Armitage, C. J. and Conner, M. (2001). Efficacy of the Theory of Planned Behaviour: A meta-analytic review. British Journal of Social Psychology 40(4): 471–499.

Chiu, C.-M., Chiu, C.-S. and Chang, H.-C. (2007). Examining the integrated influence of fairness and quality on learners' satisfaction and Web-based learning continuance intention. Information Systems Journal 17(3): 271–287.

Dillman, D. A., Phelps, G., Tortora, R., Swift, K., Kohrell, J., Berck, J. and Messer, B. L. (2009). Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (IVR) and the Internet. Social Science Research 38(1): 1–18.

Elias, A., Nohmi, M., Yasunobu, K. and Ishida, A. (2016). Farmers' Satisfaction with Agricultural Extension Service and Its Influencing Factors: A Case Study in North West Ethiopia. Journal of Agricultural Science and Technology 18(1): 39–53.

Fabregas, R., Kremer, M. and Schilbach, F. (2019). Realizing the potential of digital development: The case of agricultural advice. Science 366(6471): eaay3038.

Fishbein, M. and Ajzen, I. (2010). Predicting and Changing Behavior: The Reasoned Action Approach. Taylor & Francis.

Garg, S. and Sharma, S. (2020). User Satisfaction and Continuance Intention for Using E-Training: A Structural Equation Model. Vision: The Journal of Business Perspective 24: 097226292092682.

Gopal, R., Singh, V. and Aggarwal, A. (2021). Impact of online classes on the satisfaction and performance of students during the pandemic period of COVID 19. Education and Information Technologies 26(6): 6923–6947.

Hair, J. F., Black, W. C., Babin, B. J. and Anderson, R. E. (2013). Multivariate Data Analysis. Pearson Education Limited.

Hall, A., Turner, L. and Kilpatrick, S. (2019). Using the theory of planned behaviour framework to understand Tasmanian dairy farmer engagement with extension activities to inform future delivery. The Journal of Agricultural Education and Extension 25(3): 195–210.

Hennessy, T. and Heanue, K. (2012). Quantifying the Effect of Discussion Group Membership on Technology Adoption and Farm Profit on Dairy Farms. Journal of Agricultural Education and Extension 18(1): 41–54.

Helferich, M., Thøgersen, J. and Bergquist, M. (2023). Direct and mediated impacts of social norms on pro-environmental behavior. Global Environmental Change 80: 102680.

Hollett, R. C., Gignac, G. E., Milligan, S. and Chang, P. (2020). Explaining lecture attendance behavior via structural equation modeling: Self-Determination Theory and the Theory of Planned Behavior. Learning and Individual Differences 81: 101907.

Huber, R., Bartkowski, B., Brown, C., El Benni, N., Feil, J.-H., Grohmann, P., Joormann, I., Leonhardt, H., Mitter, H. and Müller, B. (2024). Farm typologies for understanding farm systems and improving agricultural policy. Agricultural Systems 213: 103800.

Joshi, O., Chapagain, B., Kharel, G., Poudyal, N. C., Murray, B. D. and Mehmood, S. R. (2022). Benefits and challenges of online instruction in agriculture and natural resource education. Interactive Learning Environments 30(8), 1402–1413.

Kassem, H. S., Alotaibi, B. A., Muddassir, M. and Herab, A. (2021). Factors influencing farmers' satisfaction with the quality of agricultural extension services. Evaluation and Program Planning 85: 101912.

Khan, N. A., Gao, Q., Ali, S., Shahbaz, B., Khan, P. and Abid, M. (2022). Analyzing ICT-enabled agricultural advisory services in Pakistan: Evidence from a marginalized region of Punjab province. Electronic Commerce Research 22(4): 1107–1129.

Kiiza, B. and Pederson, G. (2012). ICT-based market information and adoption of agricultural seed technologies: Insights from Uganda. Telecommunications Policy 36(4): 253–259.

Klerkx, L. (2021). Digital and virtual spaces as sites of extension and advisory services research: Social media, gaming, and digitally integrated and augmented advice. The Journal of Agricultural Education and Extension 27(3): 277–286.

Klerkx, L. (2022). Advisory support and learning on non-technical aspects of farming: A key topic for extension and education research. The Journal of Agricultural Education and Extension 28(3): 251–253.

Krafft, J., Höckert, J., Ljung, M., Lundberg, S. Kolstrup, C. L. (2022). Delivering too much, too little or off target Possible consequences of differences in perceptions on agricultural advisory services. Agriculture and Human Values 39(1): 185–199.

Lu, Y., Wang, B. and Lu, Y. (2019). Understanding Key Drivers of Mooc Satisfaction and Continuance Intention To Use. Journal of Electronic Commerce Research 20(2).

Lung-Guang, N. (2019). Decision-making determinants of students participating in MOOCs: Merging the theory of planned behavior and self-regulated learning model. Computers & Education 134: 50–62.

Mathuabirami, V., Karthikeyan, C., Devi, M. N., Ganapathi, P. S. and J, P. M. (2023). Effectiveness of Extension Intervention Provided by State Department of Agriculture in Tamil Nadu during COVID-19 Pandemic. Asian Journal of Agricultural Extension, Economics & Sociology 41(9): 369–375.

Mayer, R. e. (2017). Using multimedia for e-learning. Journal of Computer Assisted Learning 33(5): 403–423.

Means, B., Toyama, Y., Murphy, R., Bakia, M. and Jones, K. (2010). Evaluation of evidence-based practices in online learning a meta-analysis and review of online learning studies. U.S. Dept. of Education, Office of Planning, Evaluation and Policy Development, Policy and Program Studies Service. https://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

Michaelis, S., Schubbert, A., Gieseke, D., Cimer, K., Zapf, R., Lühken, S., March, S., Brinkmann, J., Schultheiß, U. and Knierim, U. (2022). A comparison of online and live training of livestock farmers for an on-farm self-assessment of animal welfare. Frontiers in Animal Science 3.

Moojen, F. G., Grillot, M., de Faccio Carvalho, P. C. and Ryschawy, J. (2023). Farm advisors play a key role in integrating crop-livestock at the farm level: Perceptions and experiences in Brazil and France. The Journal of Agricultural Education and Extension 0(0): 1–25.

Österle, N., Koutsouris, A., Livieratos, Y. and Kabourakis, E. (2016). Extension for organic agriculture: A comparative study between Baden-Württemberg, Germany and Crete, Greece. The Journal of Agricultural Education and Extension 22(4): 345–362.

Segbenya, M., Bervell, B., Minadzi, V. M. and Somuah, B. A. (2022). Modelling the perspectives of distance education students towards online learning during COVID-19 pandemic. Smart Learning Environments 9(1): 13.

Shahsavar, T. and Sudzina, F. (2017). Student satisfaction and loyalty in Denmark: Application of EPSI methodology. PLOS ONE 12(12): e0189576.

Singh, A., MacGowan, B., O'Donnell, M., Overstreet, B., Ulrich-Schad, J., Dunn, M., Klotz, H. and Prokopy, L. (2018). The influence of demonstration sites and field days on adoption of conservation practices. Journal of Soil and Water Conservation 73(3): 276–283.

Sok, J., Borges, J. R., Schmidt, P. and Ajzen, I. (2021). Farmer Behaviour as Reasoned Action: A Critical Review of Research with the Theory of Planned Behaviour. Journal of Agricultural Economics 72(2): 388–412.

Tamini, L. D. (2011). A nonparametric analysis of the impact of agri-environmental advisory activities on best management practice adoption: A case study of Québec. Ecological Economics 70(7): 1363–1374.

Toma, L., Barnes, A. P., Sutherland, L.A., Thomson, S., Burnett, F. and Mathews, K. (2018). Impact of information transfer on farmers' uptake of innovative crop technologies: A structural equation model applied to survey data. The Journal of Technology Transfer 43(4): 864–881.

Yang, L. and Yang, G. (2023). Predicting disadvantaged smallholder farmers' intention to take distance learning: Evidence from China. Asia Pacific Education Review 24(3): 399–413.

Farm Income, Production, and Labor Use Under CAP: The Case of Diversified Mountain Farms in Serbia

Ružica Papić Milojević and Saša Todorović

Faculty of Agriculture, University of Belgrade, Nemanjina 6, Belgrade, Serbia, (papic.ruzica@agrif.bg.ac.rs)

ABSTRACT

The Republic of Serbia is a candidate country for accession to the European Union, which entails certain changes in agricultural and rural policy in order to harmonise it with the Common Agricultural Policy. These changes will have an impact on farmers' income, their production plans and the utilisation of resources. This paper analyses the impact of compensatory payments, greening payments and decoupled payments on farms in Areas with natural constraints in Serbia. A linear programming model was developed to simulate the effects of the proposed measures. The main results show that the simulated scenarios improve the economic situation of a diversified group of farms and preserve natural resources in Areas with natural constraints.

INTRODUCTION

Farmers in Areas with natural constraints (ANC) confront immense challenges, risks and pressures that affect their agricultural production and livelihoods. Farming in these areas is hindered by difficult geographical conditions, climatic problems, poor soil conditions, etc. In addition, these areas are usually far away from logistics centres and agricultural support services, so there is a risk of land abandonment. In the European Union (EU), farmers in ANC are supported with compensation payments which ensures a decent income and allow farmers to continue agricultural activity. There are no specific environmental commitments for this type of support, but these payments can contribute to maintain more extensive farming and discourage land abandonment (European Commission - EC, 2023). Some authors state that compensation payments are not sufficient for the development of ANC (Pelucha et al., 2013; Kazakova-Mateva, 2017), while others found that ANC payments in combination with other agricultural measures, especially those related to the environment, strengthen agricultural incomes and better protect the natural environment (Czekaj et al., 2013; Wąs et al., 2014; Zieliński et al., 2025). The researchers also analysed the impact of decoupled payments on the income and production structure of farmers in mountainous and underdeveloped regions. The results show that the effects on income and production plans depend on the type of farm (Acs et al. 2010; Shrestha et al., 2007). Previous studies also explain that diversification in marginal areas is used as a strategy mainly to reduce risk exposure (Boncinelli et al., 2017) and that farmers with diversified activities are more capable to cope with external factors – such as changes in agricultural policy (Douxchamps et al., 2016).

The effects of different policy measures on agricultural resources have generally been analysed using normative, positive and econometric mathematical programming (Buysse, 2007). Arriaza and Gomez-Limon (2003) emphasise that the classical linear programming (LP) model, despite its simple and normative nature, is still useful for estimating the impact of agricultural policies. There are many applications of LP in the field of policy analysis (Acs et al., 2010; Morgan Davis, 2014).

In Serbia, there are no special policy measures for farmers in ANC, although 28.6 % of farms and 22.8 % of utilised agricultural area (UAA) are located in these areas (Papić, 2022). Farms in ANC are mostly dependent on direct payments, which predict lower thresholds for applications from these areas. Considering the fact that Serbia is a candidate country for EU accession, the national policy is expected to be reformed in line with the Common Agricultural Policy (CAP). The aim of this paper is therefore to assess the impact of different policy scenarios on income, production plans and labour utilization on a typical farm in ANC in Serbia. We construct an LP model to simulate the effects of the following scenarios: decoupled payments; compensatory payments; greening payments and abolition of agricultural subsidies.

MATERIAL AND METHODS

Data collection and selection of typical farms

The first step of the methodology involves the collection of detailed data at farm level. The survey was conducted in the summer months of 2018 in the ANC mountain regions in the east and south of Serbia. The sample comprised 370 economically and demographically viable farms (Papić, 2021; Papić Milojević and Bogdanov, 2024). Data was collected on animal and crop production, animal nutrition, income, variable costs, household members, facilities and equipment, subsidies, future plans, etc. The second step of the methodology involves the separation of farms into groups with similar characteristics and selection of typical farms. The multivariate techniques – namely Principal component analysis (PCA) and Two-step cluster analyses were used for this purpose. The results show that 3 clusters can be distinguished: a) farms with mixed livestock production dependent on income from agriculture (197 farms from the sample) b) farms with mixed livestock production and income from salaries and pensions (103 of the farms in the sample); and c) farms with mixed livestock and crop production and diversified income (70 farms in the sample). The process of grouping the farms is explained in detail in the research (Papić, 2021; Papić Milojević and Bogdanov, 2024). The resulting typology was then used to construct real typical farms based on their similarity to the average farm situations of each cluster (Papić Milojević et al., 2022). In this paper, a farm with diversified income – fruit and livestock production was employed as a case study to illustrate the effects of changes in agricultural and rural policy measures. Therefore, we try to answer which support measures would have the most favourable effects on the sustainability of diversified group of farms and rural areas.

The selected farm is situated on mountain slopes, around 20 km from the city centre. The farm cultivates 3.4 hectares of arable land (maize, wheat and alfalfa), 3 hectares of orchards (2 hectares of cherries and 1 hectare of plums) and 7 hectares of meadows and pastures (3 hectares of the pastures are not used). The farm produces fodder on the arable land, mainly for its own use and also for sale if there is a surplus. Cherries are the most important market product, while plums are processed into brandy, which is partly sold and partly used in the household. The farm is focused on cow's milk production. The milk is mainly processed into cheese and sold on the market. Additionally, one part of calves' production is intended for market. The farm produces piglets both for the market and for household consumption. The household consists of 5 members. Two of them are fully involved in farming, the other two are unable to carry out agricultural work due to their age[1]. The youngest member of the household has a job in the formal sector, so he is occasionally engaged in the farm. The farm hires additional labour in order to complete cherry harvest. The share of subsidies in gross margin is around 5%. The farm holder uses payments per hectare and payments for quality breeding dairy. The farm holder does not utilize rural development measures and remains uncertain about their future use. However, he is interested in using the subsidies at the local level. The farm holder perceives their production relatively independent of subsidies.

Model components and descriptions

The third step of the methodology involves developing and optimising mathematical programming models which maximise an objective function within a number of limiting constraints. This technique has demonstrated strong effectiveness in analysing policies related to land use in marginal areas (Acs et al., 2010; Žgajnar et al., 2008). The model maximizes the gross margin and it is expressed by the following relationship:

Max $Z = \sum_{j=1}^{n} c_j x_j$

Subject to the linear constraints:

$\sum_{j=1}^{n} a_{ij} x_j \ (\leq, =, \geq) \mathrm{b_i};$ i=1,2,...,m

and

$x_j \geq 0;$ j=1,2,...,n

Where,

Z - gross margin of farm in Euros,

c_j - gross margin per unit of j-th activity in Euros,

x_j - the level of j-th activity,

a_{ij} - amount of i-th resource required for the j-th activity and

b_i - total available quantity of i-th resources.

The initial assumptions for the formulation of the diversified farm model in ANC are based on real data from the selected typical farm. The analysed models include comprise the following activities: crop and livestock production; purchase of livestock feed, hiring of labour, sale, consumption and processing of agricultural products and agricultural policy measures. The following constraints were integrated into the model: land constraints, market constraints, labour constraints, housing constraints, consumption constraints, agricultural policy constraints and balance constraints. An important aspect of this step is the definition of the technical coefficients (input-output coefficients), which represent the amount of resource consumed per unit of activity.

1 The available number of working hours of the farm members was based on the assumption that members who are exclusively engaged in the farm work 26 working days per month, 10 hours per day. The available working hours are reduced for members who have jobs outside the farm and for members who, due to their age, cannot work the full working hours (Krstić and Smiljić, 2003).

Scenarios definition

The baseline scenario (B) is based on the policy model applicable in 2018 in Serbia when the research was conducted (Table 1). The farm uses direct payments per hectare which are intended for arable and permanent crops for a maximum 20 hectare (34 €/ha). The payments are not intended for pastures and meadows. Additionally, the farm uses direct payments per animal head – granted for quality breeding dairy cows (212 €/head). Thresholds have been introduced for the minimum and maximum number of quality breeding dairy cows (minimum 2 and maximum 300).

Table 1. Overview of the simulated scenarios

Acronym	Short description	Simulated amounts of new measures	Requirements
B+ANC+MPG	Compensatory p. and payments for maintaining permanent grassland with the existing system of direct p.	25€/ha+31€/ha	ANC are intended for all UAA; min. 0.1 UG/ha for sheep farming
SAPS	Decoupled payments	115€/ha	Decoupled payments for all UAA
SAPS+ANC+MPG	Decoupled p. with compensatory p. and payments for maintaining permanent grassland	115€/ha+25€/ha+31€	Combination of the above-mentioned requirements
NO S.	Abolition of all forms of subsidies	-	-

Source: Authors' systematisation

The ANC scenario represents compensatory payments in accordance with the EU regulation on rural development policy[2]. They are paid annually per hectare for all categories of UAA. A minimum amount of ANC payment proposed in the EU regulation has been simulated in this paper.

The SAPS (Simplified Area Payment Scheme) scenario implies that the existing forms of coupled payments in livestock farming (per head, per litre) have been excluded from the model and new payments[3] decoupled from production are introduced. New payments per hectare were intended for all UAA (including meadows and pastures) and the amounts for direct payment per hectare will be increased compared to the current payments.

The MPG (Maintaining permanent grassland payments) scenario represents a situation when a farm uses existing pastures and it is not allowed to plow them or change their purpose (convert them into arable land, orchards, vineyards or other forms of agricultural land use). This scenario implies a new production line has been introduced sheep farming (meat and wool production)[4] and as a result, farmers started using pastures. The proposed greening payment is an annual payment per hectare calculated as 70% of the payments per hectare in Serbia.

2 ANC payment ranges from 25 euros per ha to 450 euros per ha for mountainous areas (Council Regulation (EC) No 1305/2013).

3 The amount per hectare was calculated via EU SAPS method by dividing the total realized direct payments in Serbia by the total UAA area subsidized in 2018 (Report on the State of Agriculture 2018; Directorate for Agrarian Payments, internal data).

4 During the field research, it was found that local governments give 10 sheep for free to farms that have the capacity (land and willingness) to engage in this type of production.

The No subsidy scenario (No S.) assumes the abolition of agricultural subsidies for farmers, as well as mandatory requirements related to agricultural production that farmers must fulfil.

RESULTS

The results show that all applied scenarios increase the gross margin, except for the case when subsidies are abolished. The scenario which involves maintaining permanent pastures through grazing with a coupled payments and compensation, led to the highest increase in gross margin – around 44% (B+ANC+MPG). The introduction of SAPS payments also increased the gross margin by 10.7%, and together with MPG and ANC payments by 42% (SAPS+ANC+MPG). This is not surprising because all scenarios assume that payments per hectare increase, which positively affects gross margin of the farm with diversified plant production (Fig. 1)

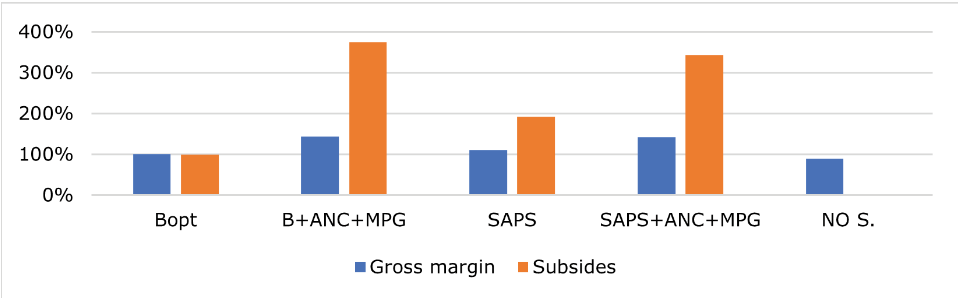

Figure 1. Changes in economic indicators under different scenarios (B=100%)

Source: Authors' calculation

The introduction of a measure for maintaining permanent pastures together with coupled and ANC payments decreases the number of pigs (and thus sale of the piglets), while the number of cattle remains unchanged. The area under wheat also decreases, unlike the area under corn and alfalfa. There were no changes in the areas under plums and cherries. The introduction of SAPS payments reduces the number of cattle by 4.3% and together with the MPG scenario by even more (-21.56%). The decrease in cattle production happens because decoupled payments do not have requirements of mandatory keeping a certain number of cattle on the farm. Also, in the MPG scenario (which includes the introduction of sheep production), the farmer receives larger amounts of payment for pastures, and this farm has no need to hire additional labour for the grazing period, so cattle production is not competitive to sheep production. The complete abolition of subsidies leads to the same changes as in the SAPS scenario (Table 2).

The largest increase in labour utilization compared to the baseline was observed in the scenarios which imply the maintenance of permanent grassland (B+ANC+MPG; SAPS+ANC+MPG). These increases are the result of the introduction of sheep farming into the model. The decrease in labour utilization occurs when the farm uses only SAPS payments and in the scenario, where subsidies are abolished (Fig 2.).

Table 2. Changes in the production structure under different scenarios compared to the Baseline (%)

Scenarios	Wheat (ha)	Maize grain (ha)	Alfalfa (ha)	Pig (su) [a]	Cattle (su) [a]	Sheep (su) [a]
Bopt	-11.3	6.0	0.0	4.2	0.0	/
B+ANC+MPG	-31.2	5.7	37.6	-17.8	0.0	100.0
SAPS	-0.3	1.2	-4.3	4.2	-4.3	/
SAPS+ANC+ MPG	-27.5	10.7	14.1	4.2	-21.6	100.0
No S.	-0.3	1.2	-4.3	4.2	-4.3	/

a As an activity in livestock production, a structural unit for individual species is used (as an aggregate) due to the need to generalize the obtained results. This means that the final category of livestock is presented in the model and the requirements and effects of the accompanying categories are expressed through the final category (Vico, 2012).

Source: Authors' calculation

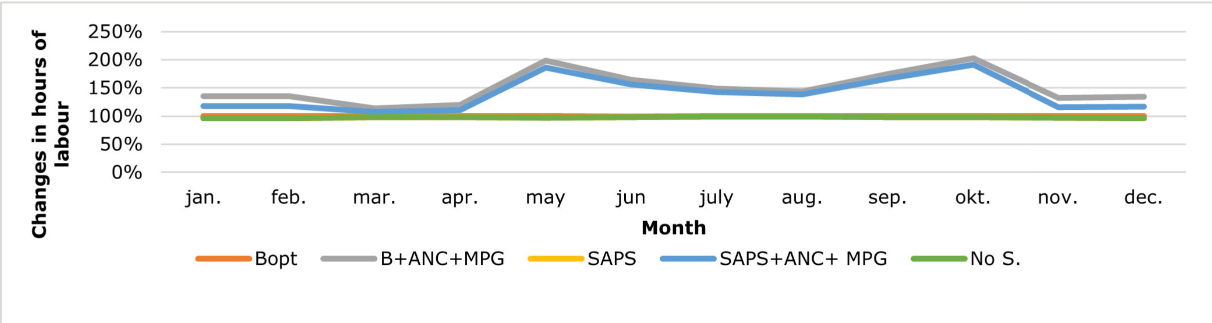

Figure 2. Changes in the use of the hours of labour force per month (B=100%)

Source: Authors' calculation

DISCUSSION

For the farm with diversified income – fruit and livestock production, scenarios which include MPG and ANC payments proved convenient in case of both coupled and decoupled payments. Namely, in both cases, additional payments (MPG and ANC) increase the gross margin and lead to the better utilization of agricultural resources, i.e. labour. Similar findings are presented in the research of Gocht et al. (2016) and Helming and Terluin (2011) who explain that the measure for maintaining permanent grassland positively affects the economic results of farms – especially for those that do not rely solely on livestock production. These results show that for farms in mountain areas different types of payment for pastures can result favourable effect on overall rural areas. This is because maintain the grazing system leads to sustainable management of the ecosystem, and economic benefits are ensured through the production and processing of traditional agricultural products.

Research shows that SAPS payments (especially in combination with greening and compensation payments) increase the gross margin of farms that have diversified their agricultural production. Previous studies show that decoupled payments cause reduction in gross margin in mountain areas only for farms with mixed livestock production (Papić Milojević et al., 2022; Manos et al., 2009; Manos et al., 2011). Also, findings from this paper show that SPAS payments reduce cattle production which is also confirmed in previous studies in marginal areas (Shrestha et al., 2007, Morgan-Davis, 2014, Acs et al., 2010). These findings explain that a diversified group of farms in ANC will benefit from SAPS payments, and therefore some mechanisms should be found to target this type of payments to these characteristic group of farms in the ANC.

Scenario where no budgetary support is assumed (No. S) decreases the gross margin, reduces the use of labour and number of cattle, indicating that farms in these areas still need policy support. Similar findings are confirmed in previous studies (Žgajnar et al., 2008; Acs et al., 2010).

CONCLUSIONS

The results of the applied scenarios indicate that instruments based on the EU model of agricultural policy and in accordance with the specificities of farms, can improve the economic situation of family farms in the ANCs and contribute to the sustainable development of these areas. In the ANC in Serbia there is a group of farms that have diversified their income and are less dependent on state support. This group, which is located in specific parts of the ANC gives priority to plant production (fruit production) that achieve a high gross margin. Therefore, instruments that favour plant production (e.g. decoupled payments) are certainly necessary for this type of farm. Also, farms in ANC have significant share of the area under meadows and pastures, so measures that influence suitable pasture management are also suitable for them. It is evident that for farms with diversified income – fruit and livestock production, abolition of the current coupled support system and the transition to decoupled support (which is mandatory in the EU policy) is not a problem. Therefore they can be easily adapt to the changes that come with the CAP policy. The research results represent a valid basis for various discussions and studies related to the creation of effective development policies and strategies in marginal areas.

ACKNOWLEDGMENT

This paper is a result of the research funded by the Ministry of Science, Technological Development and Innovations of the Republic of Serbia based on the agreement between the Ministry and the Faculty of Agriculture, University of Belgrade (Contract No. 451-03-137/2025-03/200116), on the realization and financing of scientific research in 2025.

REFERENCES

Acs, S., Hanley, N., Dallimer, M., Gaston, K., Robertson, P., Wilson, P. and Armsworth, P. (2010). The effect of decoupling on marginal agricultural systems: Implications for farm incomes, land use and upland ecology. Land Use Policy 27: 550–563.

Arriaza, M. and Gomez-Limon, J.A. (2003). Comparative performance of selected mathematical programming models. Agricultural Systems 77:155–171.

Boncinelli, F., Bartolini, F., Casini, L. and Brunori, G. (2017). On farm non-agricultural activities: geographical determinants of diversification and intensification strategy. Letters in Spatial and Resource Sciences 10: 17–2.

Buysse, J., Huylenbroeck, G.V. and Lauwers, L. (2007). Normative, positive and econometric mathematical programming as tools for incorporation of multifunctionality in agricultural policy modelling. Agriculture, Ecosystems & Environment 120: 70-81.

Czekaj, S., Majewski E. and Wąs, A. (2013). The impact of the "greening" of the Common Agricultural Policy on the financial situation of Polish farms. Applied Studies in Agribusiness and Commerce – APSTRACT 7: 49-55.

Douxchamps, S., Van Wijk, M. T., Silvestri, S., Moussa, A. S., Quiros, C., Ndour, N. Y. B., Buah, S., Somé, L., Herrero, M., Kristjanson, P., Ouedraogo, M., Thornton, P. K., Van Asten, P., Zougmore, R. and Rufino, M. C. (2016). Linking agricultural adaptation strategies, food security and vulnerability: evidence from West Africa. Regional Environmental Change 16: 1305.

Gocht, A., Ciaian, P., Bielza, M., Terres, J. M., Röder, N., Himics, M. and Salputra, G. (2016). Economic and environmental impacts of CAP greening: CAPRI simulation results. Joint Research Centre, European Commission.

Helming J.F.M. and Terluin I.J. (2011). Scenarios for a CAP beyond 2013. Implications for EU-27 Agriculture and the CAP budget. Work document 267, LEI Wageningen.

Kazakova-Mateva, Y. (2017). Effects of less favoured areas support in territories with natural constraints. Trakia Journal of Sciences 15:29-35.

Manos, B., Bournaris, T. and Chatzinikolaou, P. (2011). Impact assessment of CAP policies on social sustainability in rural areas: an application in Northern Greece. Operational Research – An International Journal 11: 77–92.

Manos, B., Bournaris, T., Papathanasiou, J. and Chatzinikolaou, P. (2009). Evaluation of tobacco cultivation alternatives under EU common policy (CAP). Journal of Policy Modelling 31: 225-38

Morgan-Davis, C. (2014). Changing role of hill farming in Scotland. Doctoral Dissertation, College of Science and Engineering, University of Edinburgh.

Papić Milojević R. and Bogdanov N. (2024). Typology of farms in areas with natural constraints – diversity of livelihood strategies and their determinants. Applied Ecology and Environmental Research 22(2):1051-1073.

Papić Milojević, R., Bogdanov N. and Todorović S. (2022): How could the CAP measures impact family farms in Areas with natural constraints in Serbia? 4th International Symposium for Agriculture and Food – ISAF 2022, Ohrid, pp. 61-74

Papić, R. (2021). Politika ruralnog razvoja prema područjima sa prirodnim ograničenjima –efekti na porodična gazdinstva i ruralne sredine u Republici Srbiji. Doctoral dissertation, University of Belgrade, Faculty of Agriculture, Serbia.

Papić, R. (2022). Rural development policy on areas with natural constraints in the Republic of Serbia. Economics of Agriculture 69, 75-89.

Pelucha, M., Kveton, V. and Jilkova, J. (2013). Territorial dimensions of agro-environmental measures and LFA in rural development policy in the Czech Republic. Land Use Policy 34:91–103.

Shrestha, S. Hennessy, T. and Hynes, S. (2007): The effect of decoupling on farming in Ireland: A regional analysis. Irish Journal of Agricultural and Food Research 46: 1–13.

Vico, G. (2012). Optimizacija govedarske proizvodnje u Republici Srpskoj na osnovu više kriterija. Doctoral dissertation, University of Belgrade, Faculty of Agriculture, Serbia.

Wąs, A., Zawalińska, K. and Britz, W. (2014). Impact of 'greening' the Common Agricultural Policy: evidence from selected countries based on CAPRI model. EAAE 2014 Congress: "Agri-Food and Rural Innovations for Healthier Societies". Ljubljana, August 26–29.

Žgajnar, J., Erjavec, E. and Kavčić, S. (2008). Change in farm production structure within different CAP schemes – an LP modelling. Annals of "Dunarea de Jos "University – Fascicle I. Economics and Applied Informatics, 31-36.

Zielinski, M., Józwiak, W., Zak, A. and Rokicki, T. (2025). Development of Eco-Schemes as an Important Environmental Measure in Areas Facing Natural or Other Specific Constraints Under the Common Agriculture Policy 2023–2027. Sustanbility 17:3-20.

European Commission (2023). Payments in areas with natural constraints– Overview and socio-economic and environmental features of farming in ANC areas based on FADN data. DG Agriculture and Rural Development, Brussels.

Implementation of Targeted Agri-environmental Schemes for Biodiversity Conservation in Croatia

Lucija Pečurlić[1], Tihana Sudarić[1], David Kranjac[1], Krunoslav Zmaić[1], Sanja Jelić Milković[1] and Tanja Šumrada[2]

[1] Josip Juraj Strossmayer University in Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia (lbencaric@fazos.hr)
[2] Biotechnical faculty, University of Ljubljana, Jamnikarjeva ulica 101, Ljubljana, Slovenia

ABSTRACT

The aim of this research was to analyse the adoption patterns of targeted agri-environmental schemes (AES) for biodiversity conservation among farmers in Croatia in the programming period 2014–2022. We present a statistical analysis of farm enrolment data from the Agency for Payments in Agriculture, Fisheries and Rural Development. Specifically, we focused on two schemes, which targeted priority grassland habitat types and species. In 2021, about 25,000 hectares from 1,012 farm holdings were enrolled in the Preservation of High Nature Value Grassland scheme (10.1.3.), and 617 hectares (126 farm holdings) were enrolled in the Pilot Measure for the Protection of the Corncrake (Crex crex) (10.1.4.). Our analysis revealed that, in both schemes, enrolled farmers were significantly younger compared to those that did not enrol, and in the Corncrake scheme, farmers also had higher education levels. However, no significant differences were observed in gender or farm type. The majority of enrolled plots were under 1 ha in size, reflecting the highly fragmented structure of Croatian agriculture. Further research is needed to better understand the underlying reasons for the low enrolment rates, especially in the Corncrake scheme. These insights could support the design of targeted advisory services and awareness-raising campaigns aimed at increasing participation among underrepresented groups, such as older farmers and those managing small, fragmented landholdings.

INTRODUCTION

The Republic of Croatia is located at the crossroads of several biogeographical regions (Continental, Alpine and Mediterranean), which, along with ecological, climatic and geomorphological conditions, make it one of the countries with the richest biodiversity in Europe (Baltaret, 2010). The Natura 2000 network in Croatia covers 36.7% of the land area and consists of 38 areas designated as Special Protection Areas based on the Birds Directive and 744 Special Areas of Conservation based on the Habitats Directive (Ministry of Economy and Sustainable Development, 2022). However, the biodiversity policy integration in the agricultural sector has been relatively weak, which is reflected in a limited array of targeted measures within the agricultural policy and a lack of capacities for collaboration between nature conservation and farming sector institutions (Radović, 2023.; Sladonja et al., 2012.; Balazsi, 2018). First targeted schemes for biodiversity conservation were thus introduced only in 2013, when the Croatian agricultural policy was harmonised with the Common Agricultural Policy (CAP) (Mikuš et al., 2019).

Designed to promote agricultural practices that contribute to environmental sustainability and enhance biodiversity, the Agri-Environment-Climate Measure (AECM) within Croatia's 2014–2020 Rural Development Programme was supported with €118 million from the European Agricultural Fund for Rural Development (EAFRD), representing approximately 5.9% of the total EAFRD allocation to Croatia (Ministry of agriculture, 2018). Within the AECM, the three key schemes for biodiversity conservation on grasslands were 10.1.3. Preservation of High Nature Value Grassland (HNV Grassland scheme) and two schemes, which targeted specific Natura 2000 sites and farmland species, namely 10.1.4. Pilot Measure for the Protection of the Corncrake (Crex crex) (Corncrake scheme) and 10.1.5. Pilot Measure for Butterfly Protection (Phengaris teleius, Phengaris nausithous, Phengaris alcon and Coenonympha oedippus) (Butterfly scheme). In all three voluntary schemes, enrolled farmers were obliged to participate for five years, to attend regular training and to document the practices they carried out in the enrolled grasslands. However, the schemes differed on, for example, mowing dates and specific agrotechnical requirements.

The voluntary character of AECM was found to be one of the key drawbacks in tackling the continued biodiversity decline at the EU level as the number of farmers who opt to enrol in the targeted and "dark green" schemes remains relatively low (Gamero et al, 2017; Pe'er et al, 2022). Participation rates in AECM have been shown to vary widely across EU Member States, largely as a result of complex and context-specific interactions between environmental conditions, economic incentives and socio-political frameworks (Podruzsik & Fertő, 2024). In recent years, a growing number of studies have thus examined different factors that influence farmers' decision-making and willingness to enrol in these schemes (Schulze et al, 2024; Klebl et al, 2023). The aim of this research was to analyse the level of enrolment and socio-economic characteristics of participating farmers in the targeted schemes for biodiversity conservation within the Croatian CAP in the programming period 2015-2022.

MATERIAL AND METHODS

The analysis was based on data from the Paying Agency for Agriculture, Fisheries and Rural Development (PAFRD) for the 2014-2022 programming period, which included data on agricultural support and structural characteristics of agricultural holdings, LPIS data and spatially referenced data on eligible areas for the HNV Grassland scheme and Corncrake scheme. The following variables were analysed: farm type, education level and age of farmers, and size of enrolled plots of grasslands. Data processing and statistics were performed in R (version 4.0.2) using the dplyr package (Wickham et al, 2023). We compared the structural and socio-economic characteristics of farmers who enrolled in the schemes with the entire population of eligible farmers using the selected statistical tests. Independent samples t-tests were used to examine the differences in the mean values of numerical variables (e.g. plot size and age), while non-parametric tests were used to analyse categorical variables. The chi-square test of independence was used to compare the distributions of gender and educational level categories between the groups of farmers who enrolled in the measure and the eligible farmers who did not enrol. For the farm type variable, Fisher's exact test was used to examine the difference in distribution with respect to the enrolment in the scheme (frequencies were less than 5).

RESULTS AND DISCUSSION

Analysis of the scheme Preservation of High Nature Value Grasslands (10.1.3.)

Our results showed that in the period from 2015-2022, 103,867 hectares or 19,393 farms were eligible to enrol in the HNV grassland scheme. However, in 2021, 1,021 farms (5.3%) enrolled 24,861 hectares (23.9%). The majority of these farms are family farms, predominantly managed by male owners, with an average age of 58 years, with secondary education as the most common level of qualification. In the analysed area, as many as 58.16% of plots are less than one hectare (ha) in size (Table 1). The smallest land plot in this scheme was 0.02 ha, and the largest was 276.56 ha. The average plot size was 5.09 ha. Both the number of farms and the number of hectares have increased since 2015 (Figures 1 and 2).

The results of the independent samples t-test showed that the average size of the plots of grasslands that were enrolled in the schemes (M = 5.10 ha) was statistically significantly higher compared to those that weren't (M = 0.89 ha) ($t = 8.244$, $df = 1039.6$, $P < 0.01$). There was also a statistically significant difference in the age of farmers ($t = -19.562$, $df = 1159.2$, $p < 0.001$) as the holders who enrolled in the scheme were on average younger (M = 50.08 years) compared to those who didn't (M = 59.65 years). However, there was no statistically significant difference in gender distribution ($X^2 = 1.8487$, $df = 1$, $p = 0.1739$), the type of farm ($p= 0.995$) and the level of education ($p = 0.3863$).

Table 1. Socioeconomic characteristics of farmers who enrolled in agri-environmental shemes High-nature Value grasslands (10.1.3.) and Corncrake protection (10.1.4.)

	HNV Grasslands		**Corncrake**	
	N	**%**	**N**	**%**
Type of farm:				
Family farm	852	82.32	139	73.94
Self-sustaining farm	123	11.88	41	21.81
Legal entities	58	5.61	8	4.25
Didn't declare	2	0.19		
Gender:				
M	766	74.01	136	72.34
F	269	25.99	52	27.66
Age:				
<45	432	41.74	61	32.45
46-65	414	40.00	79	42.02
>65	189	18.26	48	25.53
Level of education:				
Incomplete primary school	11	1.06	3	1.60
Primary school	100	9.66	17	9.04
Secondary school	486	46.96	90	47.87

Higher education, university or college	106	10.24	24	12.77
Didn't declare	332	32.08	54	28.72
Size of plots (ha)				
>1	602	58.16	139	73.94
1-10	310	29.95	45	23.94
10 to 100	119	11.50	4	2.13
>100	4	0.39	0	0

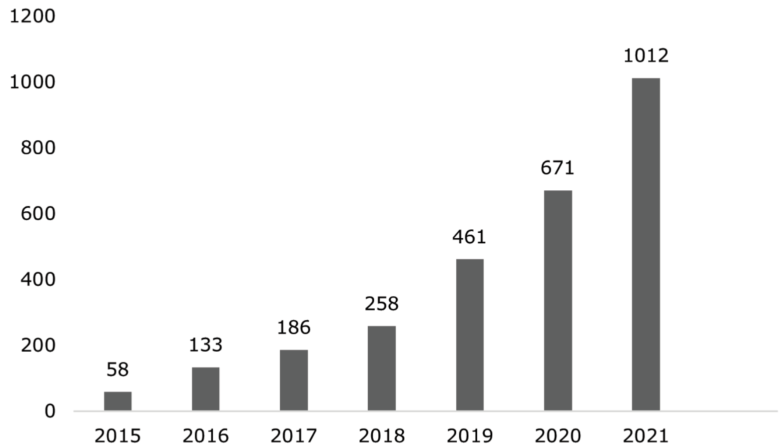

Figure 1. Number of enrolled farmers in the HNV grassland scheme in 2015-2021

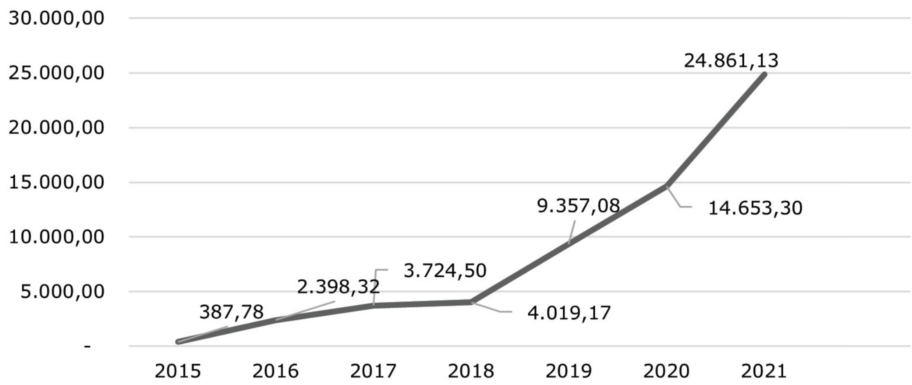

Figure 2. Number of hectares enrolled in the HNV grassland scheme in 2015-2021

Analysis of the scheme Pilot Measure for the Protection of the Corncrake (Crex crex) (10.1.4.)

In the Corncrake scheme, agricultural land must be registered in the LPIS system and designated as grassland within the ecological network, with at least 30% of the area located within a Natura 2000 site (Narodne novine, 2022). Our analysis showed that between 2015 and 2022, 7,382 farms (48,648 hectares) were eligible to enrol in this scheme. However, in 2021, only 616.84 hectares (1.3%) were enrolled by 126 farms (1.7%). The structure of farms was similar to that of the HNV grassland scheme, as the majority were family farms, predominantly managed by male owners, with an average age of 57 years. Secondary education was the most common level of qualification. In the analysed area, as many as 73.94% of plots are less than 1 ha (Table 1) with the average size of 1,24 ha. Further analysis determined that the smallest enrolled plot of grassland was just 0.04 ha in size and the largest 31.65 ha. The growth of both the number of enrolled farms and the number of hectares was observed every year (Figures 3 and 4).

The independent samples t-test results showed no statistically significant difference in the average size of the enrolled grassland plots and those that weren't ($t = 0.81$, $p = 0.4198$). A statistically significant difference was found in the age of farmers ($t = -15.481$, $p < 2.2e-16$) as enrolled farms had a lower average age of the holder ($M = 53.39$ years) compared to those that didn't ($M = 57.65$ years). There was no statistically significant difference in gender distribution ($\chi^2 = 1.2482$, $df = 1$, $p = 0.2639$) and the type of farm ($p= 0.08372$). However, a statistically significant difference was found in the education level ($\chi^2 = 11.727$, $df = 3$, $p = 0.001$); farmers who enrolled in the scheme were significantly more likely to have secondary or higher education, whereas those who did not enroll were more likely to have completed primary school or did not complete it at all.

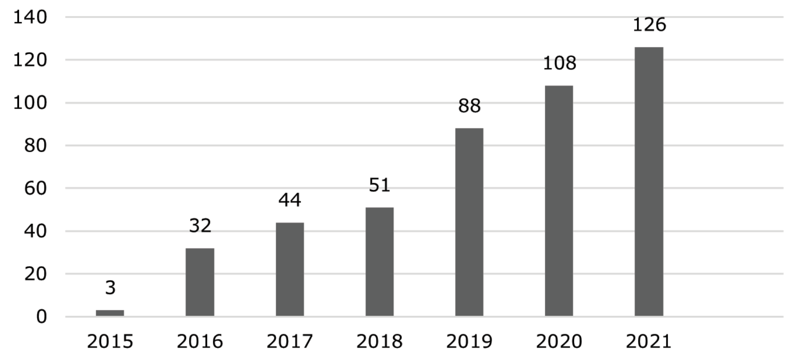

Figure 3. Number of enrolled farmers for targeted AES for corncrake in 2015-2021

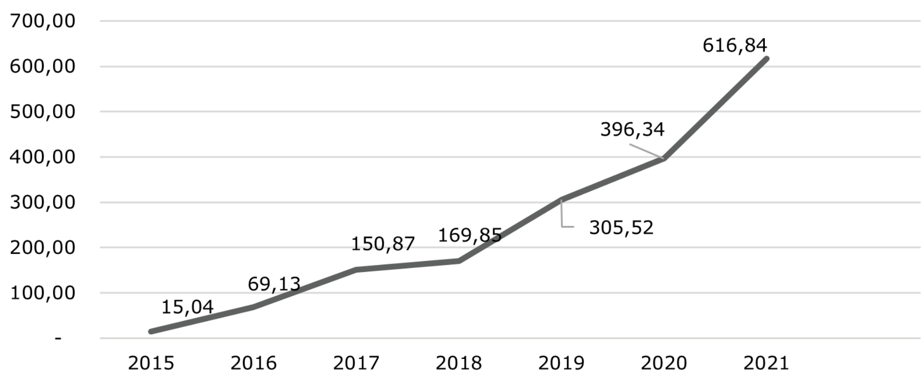

Figure 4. Number of hectares for targeted AES for corncrake in 2015-2021

The acceptance of agri-environmental and climate measures (AECM) largely depends on the characteristics of agricultural holdings and farmers. For example, family farms tend to be more reluctant to participate in AECM compared to commercial farms (Capitanio et al., 2011), while wealthier, larger and more specialised farmers in terms of production (Grammatikopoulou et al., 2016; Cullen et al., 2021) are generally more willing to adopt such measures. However, the vast majority of enrolled plots in Croatia were less than 1 hectare in size, which probably reflects the structural characteristics of Croatian agriculture with high land fragmentation and the predominance of small farms. Demographic factors, such as the age and education of farmers, can also play an important role in the adoption of AECM. For example, research on the adoption of agri-environmental schemes for grassland conservation in Slovenia, showed that older farmers were generally less inclined to participate in the scheme due to concerns about administrative burden and potential personal health-related issues, and reluctance to burden their successors with long-term commitments (Novak et al., 2022). This might explain why younger farmers were more likely to enrol in both of the analysed schemes.

CONCLUSIONS

Our analysis has shown relatively low participation levels in both analysed schemes, with only 23.9% of eligible grasslands enrolled in the Grassland scheme in 2021, and 1.3% of eligible hectares in the Corncrake scheme. Given that the target values, which were set in the Prioritised Action Framework for the Natura 2000 sites in Croatia for the programming period 2021-2027, are considerably higher (namely 25,000 ha for the Grassland scheme and 4,000 ha for the Corncrake scheme, respectively) (Narodne novine, 2022), there is a pressing need to adjust the design and implementation of both schemes to increase the enrolment rates among farmers. To effectively address the low enrollment rates, we recommend conducting in-depth analyses to uncover the specific barriers faced by farmers. Based on these insights, tailored advisory services and well-targeted information campaigns should be developed, focusing particularly on groups with consistently lower participation, such as older farmers and those managing fragmented land structures.

REFERENCES

Balázsi, Á., 2018. Grassland management in protected areas – implementation of the EU biodiversity strategy in certain post-communist countries. Hacquetia 17: 73–84.

Baltaret, A., 2010. Particularities and threats on the biodiversity from Croatia. Journal of tourism 10: 42–47.

Capitanio, F., Adinolfi, F. and Malorgio, G. (2011). What explains farmers' participation in Rural Development Policy in Italian southern region? an empirical analysis, N. Medit. 10(4): 19-24.

Cullen, P. Hynes, S. Ryan, M. and O'Donoghue, C. (2021). More than two decades of Agri-Environment schemes: Has the profile of participating farms changed? J Environ Manage. 292: 112826

Grammatikopoulou, I., Pouta, E. and Myyrä, S. (2015). Exploring the determinants for adopting water conservation measures. What is the tendency of landowners when the resource is already at risk? Journal of Environmental Planning and Management 59(6): 993–1014.

Gamero, A., Brotons, L., Brunner, A., Foppen, R., Fornasari, L., Gregory, R.D., Herrando, S., Hořák, D., Jiguet, F., Kmecl, P., Lehikoinen, A., Lindström, Å., Paquet, J.-Y., Reif, J., Sirkiä, P.M., Škorpilová, J., van Strien, A., Szép, T., Telenský, T., Teufelbauer, N., Trautmann, S., van Turnhout, C.A.M., Vermouzek, Z., Vikstrøm, T. and Voříšek, P. (2017). Tracking Progress Toward EU Biodiversity Strategy Targets: EU Policy Effects in Preserving its Common Farmland Birds. Conservation letters 10: 395-402.

Klebl, F., Feindt, P.H. and Piorr, A. (2024). Farmers' behavioural determinants of on-farm biodiversity management in Europe: a systematic review. Agric Hum Values 41: 831–861.

Ministry of Ministry of Economy and Sustainable Development (2018). Prioritised action framework (PAF) for NATU-RA 2000 in the Republic of Croatia, Retrieved from https://mingo.gov.hr

Ministry of Agriculture (2023a). Godišnje izvješće o stanju poljoprivrede u 2022, Zagreb. Retrieved from https://poljoprivreda.gov.hr

Ministry of agriculture (2018). Rural Development Programme of the Republic of Croatia for the Period 2014-2020. Retrieved from https://ruralnirazvoj.hr

Ministry of Agriculture (2015). Rural Development Programme of the Republic of Croatia for the Period 2014-2020. Version 1.4. Retrieved from https://ruralnirazvoj.hr

Mikuš, O., Ravlić, M., Hadelan, L., Jež Rogelj, M. and Ljubaj, T. (2019). The role of agricultural policy in the relationship between agriculture and the environment. Presented at the 54th Croatian & 14th International Symposium on Agriculture. Proceedings, University of Zagreb, Faculty of Agriculture, Vodice, 143–147.

Narodne novine (2022). Odluku o donošenju programa financiranja ekološke mreže Natura 2000. Retrieved from https://narodne-novine.nn.hr

Narodne novine (2022). Pravilnik o provedbi izravne potpore poljoprivredi i IAKS mjera ruralnog razvoja za 2022. Godinu. Retrieved from https://narodne-novine.nn.hr

Novak, A., Šumrada, T., Černič Istenič, M. and Erjavec, E. (2022). Farmers' decision to participate in agri-environmental measures for the conservation of extensive grasslands in the Haloze region. Acta Agriculturae Slovenica 118(1): 1–16.

Pe'er, G., Finn, J. A., Díaz, M., Birkenstock, M., Lakner, S., Röder, N., Kazakova, Y., Šumrada, T., Bezák, P., Concepción, E. D., Dänhardt, J., Morales, M. B., Rac, I., Špulerová, J., Schindler, S., Stavrinides, M., Targetti, S., Viaggi, D., Vogiatzakis, I. N. and Guyomard, H. (2022). How can the European Common Agricultural Policy help halt biodiversity loss? Recommendations by over 300 experts. Conservation Letters 15: e12901.

Podruzsik, S. and Fertő, I. (2024). Motivations for farmers' participation in agri-environmental scheme in the EU, literature review. Open Agriculture 9(1).

Radović, J. (2023). Republic of Croatia, in: Tucker, G. (Ed.), Nature Conservation in Europe: Approaches and Lessons. Cambridge University Press, Cambridge, 200–218.

Sladonja, B., Brščić, K., Poljuha, D., Fanuko, N. and Grgurev, M. (2012). Introduction of Participatory Conservation in Croatia, Residents' Perceptions: A Case Study from the Istrian Peninsula. Environmental Management 49: 1115–1129.

Schulze, C., Zagórska, K., Häfner, K., Markiewicz, O., Czajkowski, M. and Matzdorf, B. (2024). Using farmers' ex ante preferences to design agri-environmental contracts: A systematic review. Journal of Agricultural Economics 75: 44–83.

Wickham, H., François, R., Henry, L., Müller, K., Vaughan, D. (2023). dplyr: A Grammar of Data Manipulation. R package version 1.1.4, https://github.com/tidyverse/dplyr, https://dplyr.tidyverse.org.

The Influence of Agricultural Land Structure on the Identification of Typical Family Dairy Farms in the Republic of Croatia

Maja Petrač[1], Krunoslav Zmaić[1], David Kranjac[1], Lucija Pečurlić[1] and Jaka Žgajnar[2]

[1] Josip Juraj Strossmayer University in Osijek, Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia (mpetrac@fazos.hr)

[2] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana, Slovenia

ABSTRACT

This paper presents the results of a cluster analysis conducted to identify typical dairy family farms in Croatia, based on four key variables related to land use. The objective is to determine the most representative farm types that can serve as a foundation for analysing the current state of the Croatian dairy sector. The analysis specifically investigates whether to allocate a greater proportion of land to pastures for grazing or to arable land for cultivating fodder crops. It also identifies the most commonly grown crops used for animal feed. Using these insights, we will develop farm models supported by a mathematical programming approach. The analysis is based on real-world data provided by the Croatian Agency for Agriculture and Food. It employs both hierarchical and non-hierarchical clustering methods using IBM SPSS Statistics software. The results offer a valuable basis for the development of farm-level models and support further research and evidence-based policy planning in the Croatian dairy sector.

INTRODUCTION

The long-term decline in the number of dairy farms, livestock, and overall milk production reflects an ongoing consolidation process typical of the agricultural sector (Gonzalez-Mejia et al., 2018), which is taking place across the entire European Union, including in Croatia. At the same time, the adoption of new technologies has contributed to an increase in milk yield per cow (Mijić et al., 2021). While small-scale farms are the most affected, often transitioning to arable farming, larger farms have recorded a modest increase in production (Očić et al., 2023). Given the unfavourable conditions and the limited effectiveness of current policy measures, a comprehensive analysis of the sector is required, alongside the development of more effective strategies for recovery. Specifically, there is a need for decision-support models that can offer deeper insight into the state of agricultural holdings and guide evidence-based policymaking (Ciaian et al., 2013). Strategic plans under the EU CAP increasingly incorporate simulation models at both the farm-level and aggregated scales (Lovec et al., 2020).

Before developing a representative model for Croatian dairy farms, it is essential to identify and classify typical farms based on shared characteristics and production capacities. Grouping dairy farms with similar profiles will enable a more accurate and relevant analytical approach (Chibanda et al., 2022). Poczta et al. (2020) identified five types of dairy farms in the EU using cluster analysis of FADN data. Croatian farms, according to average indicators, are classified into the first type, together with Slovenia, Austria, Poland, and Romania. These countries share a number of common structural and economic characteristics that clearly differentiate them from other members of the European Union. Cluster analysis is a widely used method for identifying groups of representative farms, or so called typical farms (Pečnik et al., 2022). However, the outcome of such an analysis is not definitive, as it can vary depending on several factors within the analytical process, such as whether a hierarchical or non-hierarchical method is used, or which specific approach is applied within hierarchical clustering. Additionally, the choice of variables plays a crucial role in shaping the final grouping. Therefore, it is essential to carefully assess and justify the inclusion of each variable before including it in the analysis, as it directly influences how similarities between farms are measured.

In this paper, we present a set of variables related to the purpose of agricultural land use on dairy farms. Agricultural land is a key resource for dairy farms, serving not only as the primary source of feed for livestock but also as a foundation for economic profitability and environmental sustainability. The main objective is to analyse how agricultural land is utilised, with a specific focus on its primary function, by classifying dairy farms according to the dominant use of their land. This approach allows for a more detailed insight into the size, distribution, and purpose of agricultural land on farms specialized in milk production, factors that significantly influence the technology and efficiency of animal feed production.

The aim is to assess whether family dairy farms allocate more land to grazing or crop production, and to identify the main feed crops used. As feed systems impact both herd nutrition and manure management, land use strategies must support sustainability and address food security and environmental goals (N.P. Martin, 2017). The non-uniqueness of cluster analysis results stems from the choice of algorithm, distance metrics, and initial conditions can lead to different but equally valid solutions, The derived groupings will serve as a preliminary step in further research aimed at defining typical dairy farms. These will include not only land use characteristics but also production parameters and technology aspects. The final farm types will be validated and refined through expert workshops with agricultural consultants and experts, and further developed using the Slovenian SiTFarm model (Žgajnar et al., 2022). SiTFarm is a microsimulation tool based on mathematical programming that is an example of a bioeconomic farm model (BEFM).

MATERIALS AND METHODS

The empirical data used in this analysis were obtained from the Croatian Agency for Agriculture and Food (HAPIH). The data are collected from all agricultural holdings in Croatia that supply milk, with farmers reporting in a standardized format with relevant operational details. The initial database consisted of 4,198 registered dairy farms, recorded at the individual farm level. These records were supplemented with additional data from the Agency for the year 2022. During data preparation, efforts were made to resolve issues such as multiple identifiers, duplicate entries, and erroneous records (e.g., farms reporting zero cows). After thorough data cleaning and reconciliation, the final dataset comprised 3,393 dairy farms. Of these, 3,331 are categorized as family farms, while 62 are registered as legal entities. This paper focuses exclusively on the analysis of agricultural land use among family farms.

Statistical data processing was performed using the IBM SPSS Statistics V22.0 software package. Descriptive statistics for the variables used in cluster analysis are presented in Table 1. Unlike the previous cluster analysis on these data (Petrač et al, 2023) when the quantitative variables Number of cows (NOC), Annual delivery of milk (ADOM), Number of plant cultures (NOPC) and Area under culture (AUC) and Region (REG), (Petrač et al, 2024), the present study focuses on a different set of quantitative variables: AL - arable land for growing crops, PL - pasture land designated for cow grazing, ML - meadow land and OP - agricultural land for other purposes (e.g. vineyards, orchards, nurseries).

For each of these four variables, key descriptive statistics were calculated, including the mean, standard deviation (SD), minimum (Min), maximum (Max), and interquartile range (Q1–Q3), as summarized in Table 1.

Table 1. Descriptive statistics for family dairy farms

Variable Name	Variable	Mean	SD	Min	Max	Q1	Q2	Q3
ML	meadow land (ha)	3.11	5.31	0.00	131.32	0.49	1.79	3.90
AL	arable land (ha)	19.27	27.93	0.00	436.91	5.14	10.52	22.25
PL	Pasture land (ha)	0.67	5.01	0.00	163.80	0.00	0.00	0.00
OP	land with other purposes (ha)	0.63	5.60	0.00	169.94	0.00	0.00	0.09

The cluster analysis was first carried out on all the mentioned variables. Initially, a hierarchical (agglomerative) clustering approach was performed using Ward's method. This was followed by a non-hierarchical clustering approach, i.e., k-means algorithm, which was performed (Scitovski et al, 2022). The squared Euclidean distance was chosen as the distance measure. All algorithms were applied to standardized data. Among numerous solutions, one solution was selected as the most suitable for further analysis. Based on the visual interpretation of the dendrogram, the optimal number of clusters was identified and sub-sequently used as the input value for the k-means method.

RESULTS AND DISCUSSION

In 2022, family dairy farms delivered a total of 244,021,361.81 kg of milk, with an average delivery of 73,257.69 kg per farm, which accounts for 57.97% of the total national milk delivery in Croatia in that year. These farms cultivated a total of 78,885.98 ha, which represents 38% of the total agricultural land used by dairy farms in Croatia. The average land size per dairy farm was 23.68 ha, a significant increase from 2.7 ha in 2002 (Bosnić et al, 2003). One reason could be the trend of farm consolidation, i.e., many smaller farms have merged or been taken over by larger ones, which has resulted in an increase in the average size of farms and their arable areas.

According to the intended distribution of land, arable land dominates, occupying 64,189.63 ha (81.37%), followed by meadows (10,350.09 ha; 13.12%), continental grassland (2,246.30 ha; 2.85%), and a minor share of other land uses (2.66%) – including karst pastures (2.17%), orchards (0.30%), vineyards (0.13%), olive groves (0.05%), and mixed perennial plantations (0.01%) (Table 2). The majority of land is concentrated in Pannonian Croatia (according to Level 2 Statistical Regions (HR NUTS 2)), consistent with expectations based on its agricultural capacity.

Table 2. Distribution of land by purpose and NUTS regions of family dairy farms

	NOC	%	ML (ha)	AL (ha)	PL (ha)	OP (ha)	AUC (ha)	%
City of Zagreb	232	0%	118.51	263.73	0.47	1.85	384.56	0%
Pannonian Croatia	27,436	56%	4,940.71	39,895.42	1,846.72	481.30	47,164.14	60%
Northern Croatia	19,042	39%	4,369.45	21,265.06	396.67	144.00	26,175.19	33%
Adriatic Croatia	2,536	5%	921.42	2,765.42	2.44	1,472.81	5,162.09	7%
Total	**49.246**	**100%**	**10,350.09**	**64,189.63**	**2,246.30**	**2,099.96**	**78,885.98**	**100%**

Among the field crops, maize is the most widely grown crop, cultivated on 28,045.10 ha (44%) (Figure 1). Its dominance is not surprising as it is a key energy source in animal feed and is indispensable in silage production, which is particularly important for the nutrition of dairy cows during the winter. In addition to maize, significant crops include winter wheat (12%), grasses and forage (10%), alfalfa (9%) and winter barley (5%), all of which can serve as additional sources of animal feed and play a key role in providing nutrients needed for milk production. It is important to note that the upcoming weather conditions will make it difficult to maintain cropping systems with limited diversity (i.e., monocultures or simple annual crop rotations in two phases). Therefore, grasslands could become an even more important way of diversifying agricultural systems (Sanderson et al., 2009).

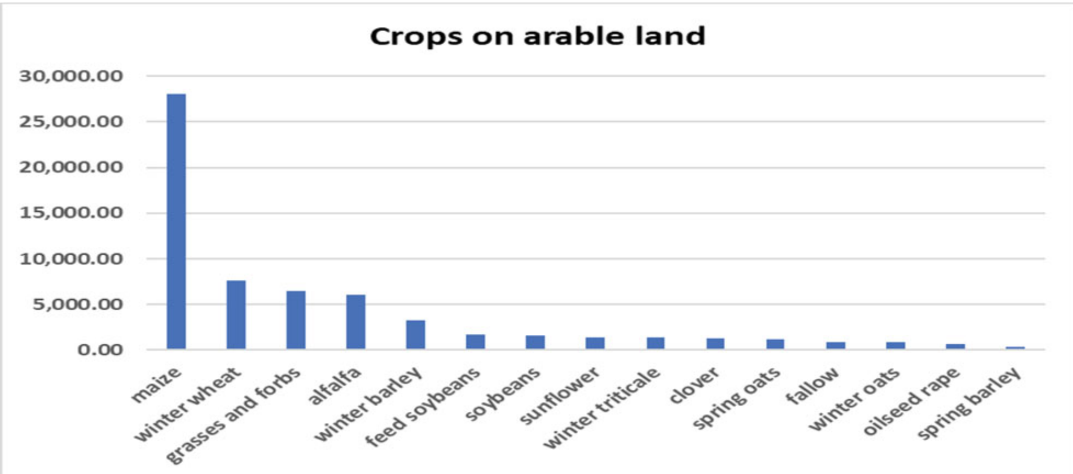

Figure 1. Crop distribution on arable land of family dairy farms

Further, we briefly present the results of the cluster analysis. First, we show the dendrogram to illustrate the hierarchical structure among the farms. Then, we present the results of the k-means clustering, which divides the family farms into 15 distinct clusters. For each cluster, we identify which farms belong to it, describe its key characteristics, and report how many farms it contains. We also highlight the average size of meadows, arable land, and other land types within each cluster. This allows us to see how land is represented across the different groups, which is the primary aim of this analysis. The initial step in the cluster analysis involved determining the optimal number of clusters through the examination of a dendrogram (Figure 2), constructed using Ward's hierarchical method and the squared Euclidean distance as the dissimilarity measure.

The dendrogram shows how farms group based on similar characteristics. As the number of clusters decreases, the variation within each cluster increases. While the dendrogram provides guidance, the final choice of the number of clusters depends on expert judgment. Based on this assessment, the analysis determined that a 15-cluster solution most appropriately captures the diversity among the observed farms. The number of clusters was determined by analyzing changes in linkage heights within the dendrogram, generated using Ward's method, where pronounced discontinuities in the hierarchical structure indicated the optimal level for cutting the tree.

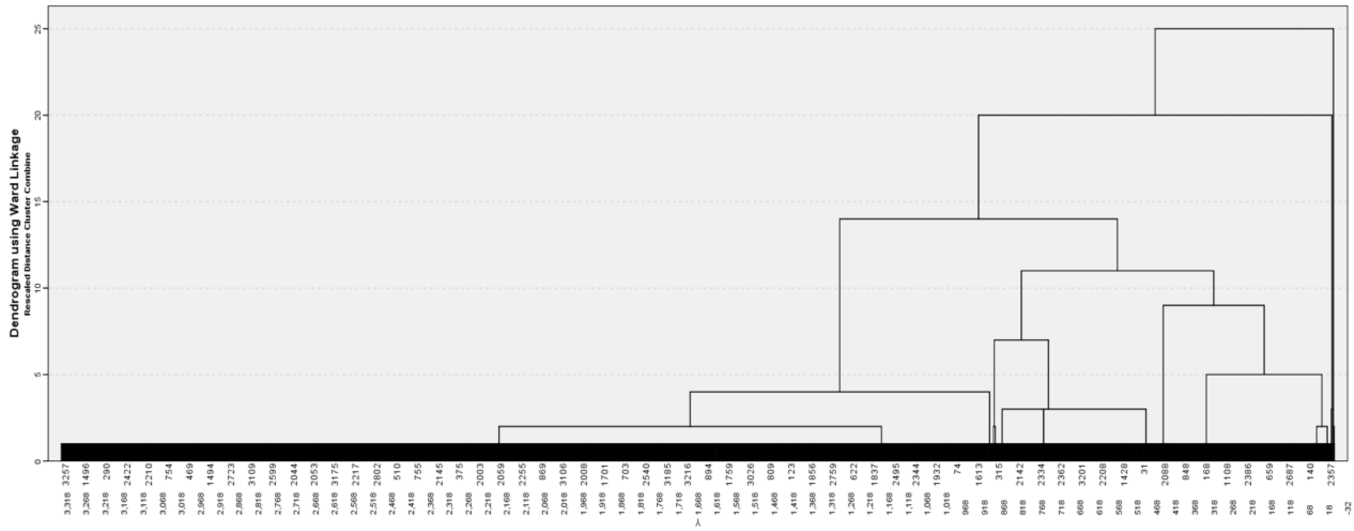

Figure 2. Dendrogram of family dairy farms according to variables (ML, AL, PL, OP)

Table 3. Cluster structure family dairy farms

Cluster	Number of farms	Average NOC	Average ML	Average AL	Average PL	Average OP	Average NOPC	Average AUC	Yield per cow
unit of measurement			ha	ha	ha	ha		ha	kg/cow
1	2,580	9.95	2.14	9.94	0.29	0.41	5.95	12.79	4,102.20
2	436	28.70	2.29	48.87	0.69	0.18	7.39	52.03	5,229.89
3	219	22.36	14.88	24.47	1.12	2.30	7.30	42.77	4,601.36
4	60	67.30	3.13	141.84	1.20	1.17	8.53	147.33	6,538.15
5	14	15.36	2.66	20.79	0.19	4.38	8.14	28.03	4,752.60
6	8	64.13	3.34	97.43	54.08	0.11	7.63	154.95	3,635.45
7	4	270.50	6.31	360.64	8.86	0.00	7.25	375.81	6,831.80
8	2	10.50	0.00	32.29	0.00	22.75	5.50	55.04	4,828.21
9	2	16.00	0.97	39.44	0.00	13.82	6.50	54.22	3,751.04
10	1	106.00	111.96	225.09	0.00	60.18	8.00	397.23	7,105.20
11	1	21.00	5.76	21.81	109.57	0.00	6.00	137.14	1,338.29
12	1	20.00	19.88	230.88	91.48	0.00	11.00	342.24	547.20
13	1	23.00	131.32	53.49	0.00	169.94	6.00	354.75	4,099.39
14	1	37.00	0.60	141.39	32.42	22.41	15.00	196.82	4,889.86
15	1	47.00	13.11	34.86	163.80	0.00	8.00	211.77	599.15
Grand Total	**3,331**	**14.78**	**3.11**	**19.27**	**0.67**	**0.63**	**6.29**	**23.68**	**4,329.80**

Legend: NOC-Number of cows, AL-arable land for growing crops, PL-pasture land designated for cow grazing, ML-meadow land, OP- agricultural land for other purposes, NOPC-Number of plant cultures, AUC-Area under culture

After deciding that there would be 15 clusters, using the k-means algorithm, the farms were distributed into 15 clusters. Table 3 shows the structure of all clusters after the implementation of k-means.

As can be seen from the table, 2,580 farms (77%) belong to cluster 1. This is the largest cluster by the number of farms, the average number of cows in this cluster (9.95) is less than the average number of cows in the Republic of Croatia (14.78), the average land area on the farm (12.79 ha) is less than the national average of 23.68 ha, the average area of meadows, arable land, pastures and other (2.14 ha, 9.94 ha, 0.29 ha and 0.41 ha) is also less than the national average (3.11 ha, 19.27 ha, 0.67 ha and 0.63 ha). This implies that most family dairy farms are located in cluster 1, which consists of very small farms with little arable land, meadows, pastures, and other.

Cluster 2 comprises 436 farms (13%) and bears some resemblance to cluster 1 in structure, however, farms in this group have much more agricultural land than farms in cluster 1. These are farms that have an average of 48.87 ha of arable land and 28.7 cows, and as such are larger than the average farm in the Republic of Croatia. Despite this, the relatively moderate herd size suggests that dairy farming may not be the primary production focus for these holdings.

Cluster 3 includes 219 farms (7%). In this cluster, too, farms have larger areas of agricultural land than the average in the Republic of Croatia. However, unlike cluster 2, the larger share of meadows is particularly notable here – the average area of meadows is 14.88 ha, which is many times higher than the national average of 3.11 ha. In addition, the average area of arable land is 24.47 ha. The average number of cows is not large, but it can still be concluded that these are farms that are primarily not engaged in dairy farming.

Cluster 4 stands out as the only group with average values exceeding national benchmarks across all key indicators. Consisting of 60 farms (2%), this cluster exhibits an average of 67.3 cows and 147.33 hectares of total agricultural land per farm substantially higher than the national average of 23.68 hectares. Notably, these farms also demonstrate superior productivity, with an average milk yield of 6,538.15 kg per cow, which is higher than the Croatian average (4,329.8 kg). These attributes indicate a high level of specialization in dairy production and signal potential for further development and investment, consistent with findings by Žgajnar and Kavčič (2024) regarding high-performing Slovenian dairy farms.

From cluster 5 onwards, most clusters contain relatively few farms, often representing unique or outlier cases. Cluster 7 is interesting as it also includes four farms that are above-average farms in terms of both the average number of cows and the size of agricultural land as well as milk yield per cow, and cluster 10, which consists of one large farm.

The other clusters are isolated cases, consisting of 1 farm with a lot of arable land and few cows and a relatively low average production per dairy cow, which limits the scope for greater investments needed for the further growth and development of these farms. For this study, clusters comprising isolated cases were not subject to detailed analysis. These cases will be examined in the subsequent phase, following the development of the aforementioned model. Parzonko et al. (2024) state that in the EU, including Croatia, there is a great diversity of dairy farms in terms of scale and production technology.

CONCLUSIONS

This study highlights the diversity and structural complexity of Croatian family dairy farms, emphasizing agricultural land use as a key factor in their classification. Despite a continued national decline in the number of dairy farms and total milk production, the findings reveal that a significant number of family farms remain active, though often constrained by limited land resources and production capacity.

Cluster analysis identified 15 distinct groups, with the vast majority (77%) concentrated in a single cluster characterized by small herd sizes and minimal agricultural land. In contrast, only a few clusters represent larger, more productive farms with sustainable development potential. These results underscore the dual nature of the Croatian dairy sector: a predominant base of small-scale, low-yield farms alongside a smaller group of specialized, high-performing operations.

By categorizing farms according to land use patterns - particularly the distribution between arable land, pastures, and meadows this research offers a robust basis for developing tailored, evidence-based policy measures. Furthermore, the classification framework serves as a preliminary step toward the development of representative farm models, which can inform strategic planning, guide investment decisions, and support long-term sustainability in the Croatian dairy sector.

REFERENCES

Bosnić, P., Mikulić, D., Vujčić, T., Marković, B. and Knjaz, V. (2003). Milk production in Croatia. Agriculturae Conspectus Scientificus 68: 203-207.

Ciaian, P., Espinosa, M., Gomez Y. Paloma, S., Heckelei, T., Langrell, S., Louhichi, K., Sckokai, P., Thomas, A. and Vard, T. (2013). Farm level modelling of the CAP: a methodological overview. Publications Office of the European Union.

Chibanda, C., Agethen, K., Deblitz, C., Zimmer, Y., Almadani, M. I., Garming, H., Rohlmann, C., Schütte, J., Thobe, P., Verhaagh, M., Behrendt, L., Staub, D. T., and Lasner, T. (2020). The Typical Farm Approach and Its Application by the Agri Benchmark Network. Agriculture, 10(12): 646.

Croatian Agency for Agriculture and Food. (2023). Annual report for 2022. Centre for Livestock Breeding, Cattle breeding.

Croatian Bureau of Statistics. National classification of statistical regions 2021 (HR_NUTS 2021). National Gazette (in Croatian) (125/2019).

Gonzalez-Mejia, A., Styles, D., Wilson, P. and Gibbons, J. (2018). Metrics and methods for characterizing dairy farm intensification using farm survey data. PLOS ONE 13(5): e0195286.

Hatfield, J. L., L. Wright-Morton and Hall, M. B. (2017). Vulnerability of grain crops and croplands in the Midwest to climatic variability

and adaptation strategies. Clim. Change. 122: 331-340.

Lovec, M., Šumrada, T. and Erjavec, E. (2020). New CAP Delivery Model, Old Issues. Intereconomics 55(2): 112-119.

Malcolm, S., E. Marshall, M. Aillery, P. Heisey, M. Livingston and Day-Rubenstein, K. (2012). Agricultural Adaptation to a Changing

Climate: Economic and Environmental Implications vary by U.S. Region. ERR-136. USDA-ERS, Washington, DC.

Mijić, P. and Bobić, T. (2021). Milk production and challenges in transition from conventional to robotic milking in Croatia. Acta Scientiarum Polonorum Zootechnica 20(3): 59-64.

Martin, N.P., Russelle, M.P., Powell, J.M., Sniffen, C.J., Smith, S.I., Tricarico J.M. and Grant, R.J. (2017). Invited review: Sustainable forage and grain crop production for the US dairy industry. Journal of Dairy Science 100(12): 9479-9494.

Očić, V., Šakić Bobić, B. and Grgić, Z. (2023). Economic analysis of specialized dairy farms in Croatia according to FADN. Mljekarstvo 73(1): 50-58.

Parzonko, A., Parzonko, A. J. and Bórawski, P. (2024). Economic Competitiveness of Dairy Farms from the Top Milk-Producing Countries in the EU: Assessment in 2014-2021. Agriculture 14(1): 123.

Pečnik, Ž. and Žgajnar, J. (2022). Resilience of dairy farms measured through production plan adjustments. Journal of Central European Agriculture 23(1): 207-219.

Petrač, M., Zmaić, K. and Žgajnar J. (2023). Typical family dairy farms in the republic of Croatia. 17th International Symposium on Operational Research in Slovenia, 31-34, Bled, Slovenia, September 20-22, 2023.

Petrač, M., Zmaić, K. and Žgajnar J. (2024). Typical family dairy farms in the republic of Croatia. 17th International Symposium on Operational Research in Slovenia, 31-34, Bled, Slovenia, September 20-22, 2023.

Poczta, W., Średzińska, J. and Chenczke, M. (2020). Economic Situation of Dairy Farms in Identified Clusters of European Union Countries. Agriculture 10(4): 92.

Sanderson, M. A., D. Wedin, and B. Tracey. (2009). Grassland: Definition, origins, extent, and future. Pages 57–74 in Grassland, Quietness and Strength for a New American Agriculture. W. F. Wedin and S. L. Fales, ed. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America. Madison, WI.

Scitovski, R. and Sabo, K. (2020). Klaster analiza i prepoznavanje geometrijskih objekata. Sveučilište Josipa Jurja Strossmayera u Osijeku, Odjel za matematiku.

Žgajnar, J., Kavčič, S., Tomšič, M., Zagorc, B., Brečko, J., Hiti Dvoršak, A., Moljk, B., Verbič, J., Bedrač, M., Kožar, Maja, Cunder, T. and Jerič, D. (2022). Razvoj modela za sistematično spremljanje ekonomskega položaja in analizo vpliva kmetijske politike na ravni tipičnih kmetijskih gospodarstev: zaključno poročilo. Ljubljana: Biotehniška fakulteta, feb. 2022. 437 str., ilustr.

Žgajnar, J. and Kavčič, S. (2024). Understanding the Dairy Sector in Slovenia: A Modeling Approach for Policy Evaluation and Decision Support. Sustainability 16(14): 6009.

Using Policy Support Tools to Create an Evidence-Based Policy Vision: A Participatory Vision-Building Exercise in Slovenia

Ilona Rac, Matic Soklič and Emil Erjavec

University of Ljubljana Biotechnical Faculty, Jamnikarjeva 101, Ljubljana, Slovenia

ABSTRACT

This paper presents the conceptual foundation and initial implementation of a case study under the EU-funded Tools4CAP project, which focuses on participatory, multi-level governance tools in the context of the Common Agricultural Policy (CAP). The Slovenian case study explores the potential of engaging with decision-makers and stakeholders in combining different tools in the formulation of the next CAP strategic plan (CSP). This short paper outlines the design logic, methodological tools selected, and early-stage insights gained from the process. While the study is still ongoing, the ambition of the Case study is to offer a replicable approach for other Member States exploring combinations of different tools, especially participatory methods, in CAP planning and implementation.

INTRODUCTION

Since its inception in 1962, the Common Agricultural Policy (CAP) has been shaped predominantly through top-down processes led by EU institutions, often criticised for limited transparency and limited involvement of non-state actors in decision-making (Roederer-Rynning, 2019). Historically, CAP negotiations took place behind closed doors, privileging national governments and agricultural lobbies while marginalising environmental and civil society perspectives (Greer & Hind, 2012; Termeer & Werkman, 2011). Over time, especially since the 2003 and 2013 reforms, the policy framework has seen a gradual shift toward 'more subsidiarity', giving Member States more autonomy in implementation through national CAP Strategic Plans (Jongeneel et al., 2019; Rac et al., 2020). This devolution of decision-making powers has opened new opportunities but also responsibilities for inclusive governance, accountability, and the tailoring of agricultural policy to local sustainability needs. In practice, Member states have been given the freedom and obligation to accommodate and integrate the often colliding preferences of an increasingly open circle of stakeholders (Cagliero et al., 2021). Such a setting requires evidence-based, inclusive and flexible strategic planning, which in turn demands a high level of administrative capacity, including high levels of adaptability to a changing policy environment (Erjavec et al., 2018).

In response to increasing demands for transparency, adaptability, and stakeholder inclusion in CAP strategic planning, and given the complexity of integrating the preferences of different stakeholder groups (Fischer et al., 2007), the Tools4CAP project (Bertolozzi-Caredio et al., 2023) provides, inter alia, a suite of governance tools aimed at enhancing participatory decision-making (Rac et al., 2024). The overarching goal of the project is to contribute to stronger national administrative capacity in a complex, multi-level governance setting. This paper presents the early phases of the Slovenian case study conducted within the frame of this project, which aims to pilot an integrated combination of selected tools in a real-world, policy-relevant setting, explore how participatory governance tools can make national CAP strategic planning more inclusive, evidence-based and systemic, and which factors may affect this process positively or negatively. The focus of the case study is on developing a governance process that supports the formulation of a shared vision for a sustainable Slovenian food system over the next 15 years, as well as providing a substantive basis for the CSP for the period 2023-2027.

MATERIAL AND METHODS

The case study is being conducted in Slovenia between November 2024 and September 2025. The process involves collaboration between the Ministry of agriculture, forestry and food of Slovenia (MAFF), the Bio-technical Faculty at the University of Ljubljana (BF UL), the Agricultural Institute of Slovenia, and a broad range of stakeholders representing the Quadruple Helix (policy, society, business, research). Conceptually, the case study is based on the multi-level, participatory governance framework developed in Deliverable 3.3 of Tools4CAP (Rac et al., 2024), which outlines protocols for tool selection and stakeholder engagement. The Slovenian pilot is applying a sequence of tools, selected in consultation with the MAFF to address two key CAP-relevant governance tasks, namely co-developing a shared understanding of needs and priorities, and structuring policy options.

The tools combine participatory identification of needs and priorities with scenario building based on a selection of corresponding variables and their indicators spread across the three pillars of sustainability (economic, environmental and social), as well as horizontal (AKIS-agricultural knowledge and innovation system), with metrics such as agricultural income, GHG emissions, biodiversity indices, and quality of life indicators. A small group of BF UL and external experts is supporting Ministry officials developing an initial draft of the Vision, which will then be refined through structured stakeholder engagement, including focus groups and consensus building sessions. Scenario analysis will support the exante evaluation of various CAP policy options that involve trade-offs among CAP objectives. The process includes identifying a baseline scenario and an alternative desired scenario balancing issues from all three pillars into a desirable, sustainable food system, which is to be validated with key stakeholders in a series of stakeholder workshops. Possible scenarios will be built around the current CAP and other (existing and future) European Commission documents relevant to the CAP's design and implementation, such as the results of the Strategic dialogue (Strohschneider, 2024), the announced EU-level vision, as well as any developments related to the forthcoming proposals for the new CAP programming period and Multiannual financial framework (expected in July 2025). They will also strongly reflect national policy objectives, placed within the overall EU CAP framework and strategic guidance.

As the goal was to support the needs of the Ministry, the work has been separated into two phases, one involving ministry officials, BF UL researchers and other relevant experts, and a second involving additional stakeholders in which the results of the internal process are to be tested, validated and lent democratic legitimacy.

EXPECTED OUTCOMES, CO-CREATION PROCESS AND PRELIMINARY RESULTS

In principle, the integrated application of participatory and analytical tools is expected to produce:

- A co-created Vision document with strong stakeholder ownership and political relevance
- A set of policy scenarios illustrating different policy development pathways and trade-offs between different goals
- An indicator-based monitoring tool that links scenarios to measurable outcomes
- Strengthened institutional capacity within the MAFF and stakeholder organizations
- Enhanced trust, transparency, and inclusiveness in the CAP strategic planning processes
- Improved quality of the next generation CSP, including its result orientation, flexibility and monitoring framework.

Although the case study is still underway at the time of writing, several early observations can be shared. First, the discussions at the ministry-experts level revealed that the ministry officials tasked with formulating the vision were interested in steering the vision towards a broader, integrated 'food systems' orientation, which includes issues beyond those traditionally addressed under the CAP, such as health aspects, the food environment, new genomic techniques, etc. (ministry meeting notes, 8.1.2025; cf. Galli et al., 2020; LEI Wageningen UR et al., 2016; Resnick & Swinnen, 2023). This is in line with a seeming shift at the EU level initiated by the Farm to fork strategy in 2020 (Fiala et al., 2024; Mowlds, 2020). However, once the list of potential issues and their indicators began to take form, it became clear that there are different understandings among ministry officials and experts of what constitutes a sustainable food system, its elements and trade-offs. Therefore, to initiate a more systemic discussion, a graphical representation of issues faced by the Slovenian food system was constructed by the researchers and supplemented with inputs from other researchers and ministry officials, building on the traditional division of sustainability issues into three pillars (Figure 1).

The scheme shown in Figure 1 provided a basis for a preliminary prioritization of issues, which was done in an internal workshop attended by MAFF officials and invited experts. After a presentation of the main issues, each participant was allocated a limited number of voting points (3 per sustainability pillar + 3 to be allocated freely). This exercise resulted in a shortlist of priorities (Table 1) selected for the next phase of modelling for scenario-building.

Table 1. Policy priorities selected in the internal MAFF workshop.

Economic Issues	Environmental Issues	Social Issues
• Low, unstable incomes and competitiveness • Farm management • Risk management • Consumer – price sensitivity • Productivity • Power relations in the value chain; cooperation	• Land take (urban sprawl) • Nutrient pollution • Biodiversity • Land abandonment (overgrowth) • Adapting agriculture to climate change	• Generational renewal • Possibility of rest (Substitute labour service) • Cooperation with producers, supply chains (also for smaller farms) • Ageing rural population • Abandonment of basic services in rural areas • Abandonment of farming and consequences for rural areas • Image of agriculture, perception of farmers in society

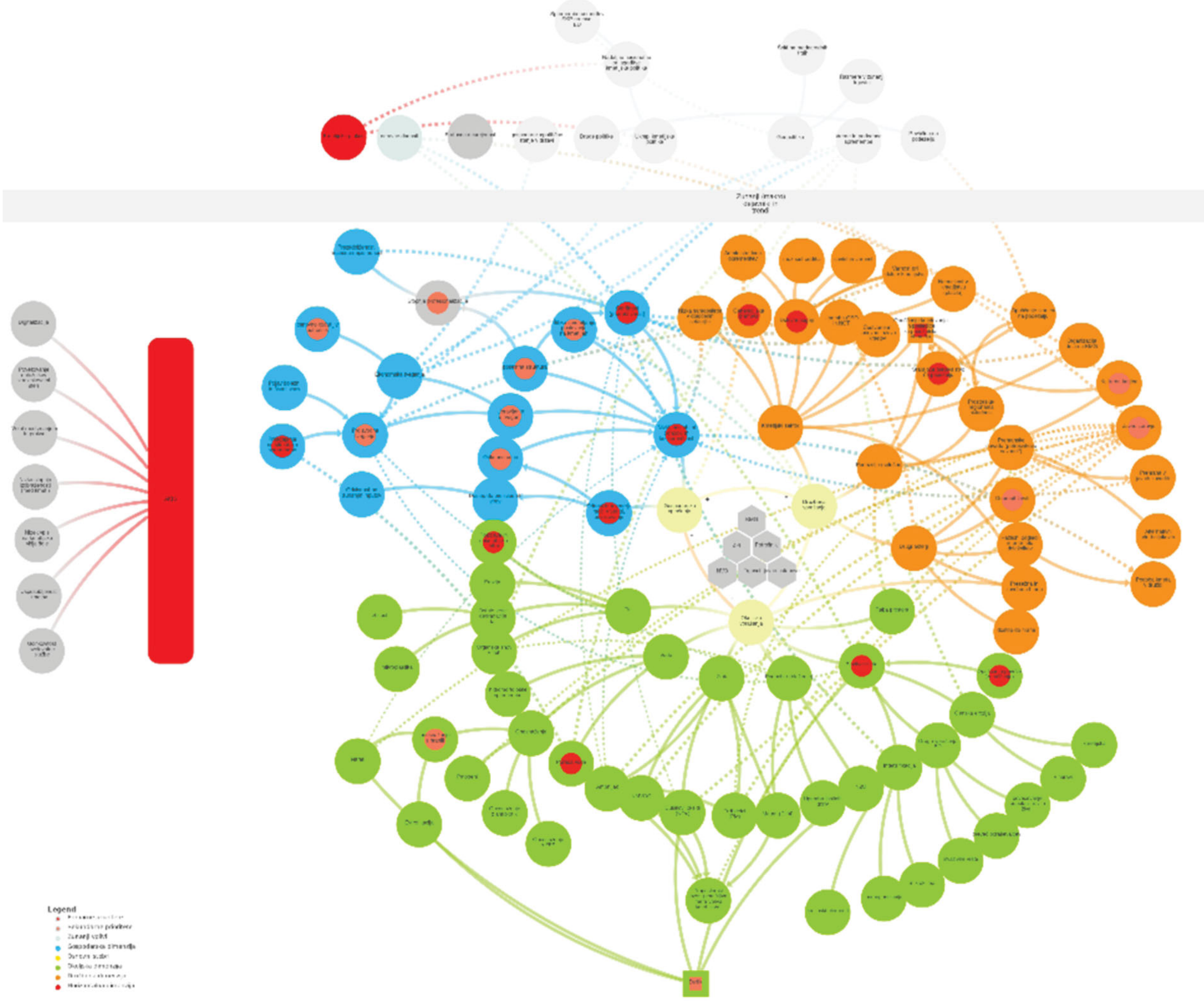

Figure 1. Visual representation of issues related to the Slovenian food system. Each coloured circle represents an issue, as conceptualized by the authors, with each colour (orange, blue, green) belonging to one pillar of sustainability; grey colours above the main scheme represent external factors and the grey-red section to the left represents the AKIS. Squares denote cross-cutting issues. The central hexagons represent players central to the food system (farmers, consumers, processors, retailers, NGOs, public institutions).

After additional discussion, certain issues were subsequently added to this list, namely AKIS – related issues, such as Educational structure, Amount of funding for AKIS, Extent of digitalization by economic size class. Discussions on further additions are still ongoing and will likely include climate change mitigation and health-related indicators, where available. At the time of writing, the BF UL team is analysing available data that measure the above issues as translated into appropriate indicators, which will feed into the design of the baseline and desirable scenarios. Future participatory process elements, which are to follow the structuring of the selected indicators into coherent scenarios, involve presenting the vision and priorities to a broader set of stakeholders and legitimizing the selected priorities and vision narrative. Subsequently, outputs of this process will be refined for integration into the Slovenian CAP Strategic Plan and potentially into other policies relevant to the food system.

DISCUSSION

The process of formulating a long-term vision for the Slovenian food system provides a strategic entry point for using policy support tools to align the CAP with broader sustainability goals across environmental, economic, and social dimensions. If successful, the case study results could demonstrate the potential of combining participatory and evidence-based tools in national policy planning. As the case study progresses, its outcomes are expected to offer transferable insights for other Member States exploring sustainable agricultural transitions through collaborative governance models. The hope of the research team is that the Slovenian case study will highlight the value of using structured participatory tools with strong stakeholder involvement to strengthen the policy's legitimacy and relevance, as well as stimulate a more comprehensive approach to planning and policy innovation.

However, despite the initial designs to steer the vision towards a food-systems perspective, this has heretofore been limited, mainly due to the fact that the process is still largely bound to and framed by the future CAP. The discussions and resulting graphic (Figure 1) reflected that the thinking of the majority those involved seems to be mostly embedded in past and current discussions of issues facing farming, rather than the food system as a whole. Furthermore, it highlighted the high level of complexity, with many interactions between different elements, which appear at different spatial and even conceptual scales. While the diagram itself was not directly usable for modelling purposes, it did help to structure thinking and provided a platform for the consideration of interactions and for prioritization. In spite of the relatively broad expertise of the involved ministry officials, researchers and other external experts, the process so far has revealed a persistent framing of issues through the lens of farm productivity and competitiveness such as low and unstable income, limited cooperation, and farm succession challenges. When prompted to reflect on broader sustainability issues, participants still tended to gravitate toward economic issues tied to the viability of individual farm holdings. Even issues falling into the 'environmental' pillar of sustainability were predominantly selected based on their implications for agricultural production. These priorities demonstrate the resilience of a productivist policy paradigm, as identified in earlier CAP literature (Greer & Hind, 2012; Pe'er et al., 2019), and mirror critiques that EU agri-food systems often default to agricultural rather than food system perspectives (Brunori et al., 2024; Fiala et al., 2024; Galli et al., 2020; Mowlds, 2020; Resnick & Swinnen, 2023). Furthermore, discussions on social issues revealed a field that was significantly less clear and structured compared to economic and environmental issues, with a less developed indicator framework. This highlights the challenge of achieving a truly integrated food system perspective in policy planning. This entrenchment is likely to be even stronger at subsequent stages of the policy process, as most stakeholder can be expected to remain subjected to siloed, sectoral thinking. This confirms the need for deeper institutional incentives to support integrated thinking across agriculture, environment, health, and rural development domains. Future processes may require more explicit framing tools, narrative techniques, or actor mapping to help participants step outside dominant paradigms.

Nevertheless, the set of highlighted issues co-developed through deliberation did include economic, environmental and social dimensions, forming a starting point for future discussions and potentially even a monitoring framework tailored to national needs. This signals potential for increased institutional learning, which is often highlighted as a critical gap in current CAP governance models (Bertolozzi-Caredio et al., 2023). While the case study will hopefully deliver meaningful outcomes in terms of a substantive vision and subsequent CSP, its deeper value may lie precisely in institutional implications. Stakeholder engagement, combined with adaptive methodological and substantive adjustments, could significantly enhance the policy community's capacity to align the policy process and applied tools with a shifting policy environment. This form of adaptive planning is particularly valuable in the CAP context, which must respond to emergent challenges such as climate change, demographic shifts, and market volatility. However, as Pe'er et al. (2019) note, the success of such approaches depends on genuine political and institutional willingness to open up decision-making spaces, not just on technical design. Practical engagement with external stakeholders has been (intentionally) scarce so far, especially in terms of opening up the discussion for stakeholders other than the habitual agricultural community. This reluctance limits the potential of the process in terms of gaining legitimacy and support, while also indicating that the need to conduct a fully participatory policy process is not yet quite internalized, nor does there seem to be sufficient institutional capacity to conduct it. Still, the relatively early stage of the process still allows for significant stakeholder engagement in subsequent phases, and this remains the MAFF's intention.

Finally, we can make some observations about the process itself. Since the case study's inception, communication with the MAFF has been central to garner the Ministry's own interest in conducting a policy process supported by the Slovenian research team. As each policy process is specific, designing an approach for formulating a CSP in a dynamic policy setting such as the one surrounding the CAP (see e.g. Daugbjerg, 1999; Patterson, 1997), is by necessity itself a dynamic undertaking. Regular communication has proven to be central, as needs have been evolving, necessitating a high level of flexibility both on the side of the Ministry and on the side of the supporting team of researchers. The gradual increase in engagement from the Ministry of Agriculture can certainly be considered a positive institutional outcome. However, at the time of writing, a fluctuation in the ministry personnel responsible for the vision process seems to be indicating a shift in policy priorities.

There are some clear limitations to our study. First, it is still ongoing, which restricts the potential for drawing final conclusions. Only once the visioning process is complete will a full assessment be possible. Evaluating the impact of the (participatory) policy process will also be challenging if for no other reason, due to the lack of appropriate impact indicators. A second limitation is that the observed process focuses solely on vision development, not on the design or implementation of concrete policy measures. As a result, any real-world impact can only be inferred indirectly, rather than demonstrated.

CONCLUSION

The Slovenian foresight and indicator development process demonstrates how participatory and systems-based tools could add both procedural legitimacy and substantive depth to CAP planning. It also shows that engagement with policy officials and additional external experts can yield a relatively comprehensive set of issues to be tackled in a more systemic approach to food systems, going outside the exclusive remit of agriculture. However, the persistence of sectoral framings, institutional inertia, and implementation gaps suggests that further work is needed to support the integration of such approaches into policy. Therefore, a possible avenue for future research is to explore potential impacts of participatory approaches on decision-making, as well as the conditions under which systemic framings could displace entrenched paradigms.

REFERENCES

Bertolozzi-Caredio, D., Dupeux, B., Witzke, P., Havlik, P., Schingo, C., Rustom, R., Jongeneel, R., Erjavec, E., Rac, I., van Asseldonk, M., Donnellan, T., Sterly, S., Wember, C., Gonzalez-Martinez, A., Dillon, E., Casares, B., Marianos, N., Van den Bossche, L., Fellmann, T., … Beber, C. (2023). TOOLS4CAP CONCEPTUAL FRAMEWORK.

Brunori, G., Carzedda, M., Iliopoulos, C., D'Haese, M., Lanfranchi, M., Lerro, M., Martino, G., Pettenella, D., Van Passel, S. and Troiano, S. (2024). Has transformation of food systems reached an impasse? Considerations on the role of agri-food research. Agricultural and Food Economics 12(1): 26, s40100-024-00308–8.

Cagliero, R., Bellini, F., Marcatto, F., Novelli, S., Monteleone, A. and Mazzocchi, G. (2021). Prioritising CAP Intervention Needs: An Improved Cumulative Voting Approach. Sustainability 13(7): 3997.

Daugbjerg, C. (1999). Reforming the CAP: Policy Networks and Broader Institutional Structures. Journal of Common Market Studies 37(3): 407–428.

Erjavec, E., Lovec, M., Juvančič, L., Šumrada, T. and Rac, I. (2018). The CAP Strategic Plans beyond 2020: Assessing the architecture and governance issues in order to achieve the EU-wide objectives. Brussels, European Parliament, Policy Department for Structural and Cohesion ….

Fiala, V., Jacob, K., Barnickel, C. and Feindt, P. H. (2024). Diverging Stories on food system transitions. A qualitative analysis of policy narratives in the public consultation on the European Commission's Farm to Fork Strategy. Journal of Rural Studies 110: 103374.

Fischer, F., Miller, G. and Sidney, M. S. (Eds.). (2007). Handbook of public policy analysis: Theory, politics, and methods. CRC/Taylor & Francis.

Galli, F., Prosperi, P., Favilli, E., D'Amico, S., Bartolini, F. and Brunori, G. (2020). How can policy processes remove barriers to sustainable food systems in Europe? Contributing to a policy framework for agri-food transitions. Sustainable Food Systems for Healthy Diets in Europe and Central Asia 96: 101871.

Greer, A. and Hind, T. (2012). Inter-institutional decision-making: The case of the Common Agricultural Policy. Policy and Society 31(4): 331–341.

Jongeneel, R., Erjavec, E., García Azcárate, T. and Silvis, H. (2019). Assessment of the common agricultural policy after 2020. In EU Bioeconomy Economics and Policies: Volume I (pp. 207–228). Springer.

LEI Wageningen UR, Fresco, L. O. and Poppe, K. J. (2016). Towards a common agricultural and food policy. Wageningen University & Research.

Mowlds, S. (2020). The EU's farm to fork strategy: Missing links for transformation. Acta Innovations 36: 17–30.

Patterson, L. A. (1997). Agricultural Policy Reform in the European Community: A Three-Level Game Analysis. International Organization 51(1): 135–165.

Rac, I., Erjavec, E., Jongeneel, R. and Wember, C. (2024). PARTICIPATORY AND MULTI-LEVEL GOVERNANCE DECISION-MAKING TOOLS: METHODOLOGICAL GUIDELINES, INCLUDING PROTOCOLS (Deliverable 3.3).

Rac, I., Erjavec, K. and Erjavec, E. (2020). Does the proposed CAP reform allow for a paradigm shift towards a greener policy? Spanish Journal of Agricultural Research 18(3): e0111–e0111.

Resnick, D. and Swinnen, J. (Eds.). (2023). The political economy of food system transformation: Pathways to progress in a polarized world. Oxford University Press.

Roederer-Rynning, C. (2019). The Common Agricultural Policy: A case of embedded liberalism. In Oxford Research Encyclopedia of Politics.

Strohschneider, P. (2024). Strategic Dialogue on the Future of EU Agriculture. European Commission. https://agriculture.ec.europa.eu/document/download/171329ff-0f50-4fa5-946f-aea11032172e_en?filename=strategic-dialogue-report-2024_en.pdf

Termeer, C. J. A. M. and Werkman, R. A. (2011). Changing closed agricultural policy communities. Critical Policy Studies 5(3): 283–298.

Transforming Surplus into Solidarity: Systems Dynamics Modelling in Support of Food Redistribution

Matic Soklič, Emil Erjavec and Ilona Rac

Biotechnical Faculty, University of Ljubljana, Kongresni trg 12, Ljubljana, Slovenia

ABSTRACT

Food loss and waste (FLW) in the EU remains a critical challenge, with 59 million tonnes wasted annually, exacerbating resource inefficiencies and greenhouse gas emissions. The objective of the study is to design a data tool that will allow policymakers and social entrepreneurs to assess the feasibility and funding needs of new initiatives addressing the problem of food surplus through redistribution. Using a Living Lab approach within the Horizon Europe RUSTIK project, we analyse data from Etri, a social cooperative that redistributes food to marginalised peoples. Through system dynamics modelling, we integrate logistics data, survey responses, and expert assessments to quantify the social and environmental benefits of redistribution. The robustness of model parameters was preliminarily confirmed by iterative validation against historical accounting data. Future work focuses on procuring additional data sources to enhance both validation and the model's applicability for diverse regional contexts.

GLOSSARY	
Term	**Definition**
Food Loss	The decrease in edible food mass throughout the production, post-harvest, and processing stages of the food supply chain, excluding retail and consumption. Common in agricultural and logistics phases.
Food Waste	Edible food discarded at the retail or consumer level, often due to spoilage, overproduction, or aesthetic standards. Occurs at supermarkets, restaurants, and households.
Food Surplus	Food that is still safe and edible but exceeds market demand.
Food Redistribution	The process of collecting surplus food and reallocating it to people in need, often via food banks, social cooperatives, or charitable organizations.
Causal Loop Diagram (CLD)	A systems-thinking tool used to visualize the interdependencies and feedback loops in food redistribution processes.
Living Lab (LL)	A user-centered, open innovation ecosystem where researchers, stakeholders, and users co-develop and test solutions in real-life environments.

PROBLEM STATEMENT

Every year, around 59 million tonnes of food are wasted in the EU, which represents a significant inefficiency in the use of limited resources such as land, fertilisers and energy, while contributing to greenhouse gas emissions (Cattaneo et al., 2021). Simultaneously, more than 42 million people in the EU cannot afford a good quality meal every second day (Eurostat, 2023), the affected often belonging to groups of marginalised people (Poczta-Wajda and Guth, 2024). In contrast to food waste, there is no periodical monitoring established on the amounts of food loss in Slovenia and the EU, and consequently on the feasibility of food redistribution. A World Wide Fund for Nature report estimates however, that 15,3% of food produced globally is lost at farm stage, amounting to 1,2 billion tonnes per year (Driven to Waste..., 2021).

RESEARCH QUESTION AND OBJECTIVES

The research aims to answer how different approaches to food redistribution and donation impact subjective well-being, assess the costs and benefits of redistribution, and explore the integration of quantitative and qualitative data for evidence-based policymaking. The objective is to design a data tool that will allow policymakers and social entrepreneurs to assess the feasibility and funding needs of new initiatives addressing the problem of food surplus through redistribution. In this process, we seek to provide data driven insights to support initiatives aiming to reduce FLW while enhancing social inclusion.

MATERIAL AND METHODS

The research is based on our work in a Living Lab (LL) of a Horizon Europe project (RUSTIK, 2025). In the LL we apply a heuristic approach, aiming to address the issue of FLW while simultaneously addressing the lack of social inclusion among marginalised individuals. The main guiding principle is the conceptual framework of Theory of Change, which is the formulation of an explicit theory of how and why the activities of a policy or programme should lead to impacts (Mayne, 2017). Through this approach, we draw on insights gained through our project partner Etri – a local social cooperative that engages in food redistribution and donation through social entrepreneurship. By analysing their logistics and accounting data, we obtained a detailed understanding of the operations of this type of organisation. Additional data has been gathered on the impact of food donation on the well-being of beneficiaries through Likert scale surveys.

Based on the data collected, we are designing an economic model using a system dynamics (SD) methodology (Coyle, 1997). The model combines quantitative data on surplus food and processing logistics with insights gathered through surveys. In this way, the model will serve as a link between the flow of food items, the social and environmental impacts, and the costs incurred.

The initial stage of SD modelling is based on devising a causal loop diagram (CLD), that describes the process in a non-linear fashion, focusing on key elements and the relationships between them (Figure 1.). Considering our overarching goal of dispersing the model by using it in support of small-scale projects, we adapted the CLD accordingly. To construct it parsimoniously, we established a standard meal unit (SMU) based on the assumption, that the meals provided are nutritionally balanced and within the recommended caloric intake for the average beneficiaries' age. Additionally, we calculated coefficients for converting food-stuffs into SMUs using categories that are internally consistent in caloric density and type of use in meal preparation. The robustness of these coefficients was preliminarily confirmed by iterative validation against historical accounting data (comparing calculated outputs with actual outputs).

DATA

The living lab' heuristic approach integrates social metrics research and data-driven innovation. Through surveys, direct observations, and the analysis of logistics data, we gathered comprehensive insights into the operational dynamics and societal impact of this type of initiative and its niche. The primary source of data and demonstration case is Etri. Their operations consist of redistributing surplus food to vulnerable groups of people in a canteen, while providing employment opportunities for marginalised individuals. They made available to us detailed records of food donations, including type, quantity, and distribution patterns, which serves as the basis for the quantitative part of the modelling process.

Expert assessments are used to fill gaps where quantitative data is unavailable, particularly regarding volunteer work contributions, supply fluctuations and its' characteristics. Expert knowledge was utilised in the first stage of the system dynamics modelling process, namely in developing the CLD. To assess the impact of food redistribution on well-being, financial security, and social inclusion, we also collected data through structured Likert-scale questionnaires. Lastly, we conducted several interviews with LAGs to understand data needs and potential applications for small scale project support.

RESULTS

Using expert assessment we established a causal loop diagram for food redistribution (Figure 1). While the modelling process is still ongoing, preliminary validation tests have shown that the model's estimates for redistributed meals using SMU conversion amounted to 27% less meals than the number of meals donated in the accounting data. This is within the expected margin, as the cooperative needs to buy some food items in order to provide balanced meals. As the use case and validation of the model is limited by data availability, our current efforts include securing additional data sources and adapting the model to different regions and approaches to food redistribution. In addition, we plan to test its applicability in support of a call for proposals and its implementation in a Local Action Group (LAG) project.

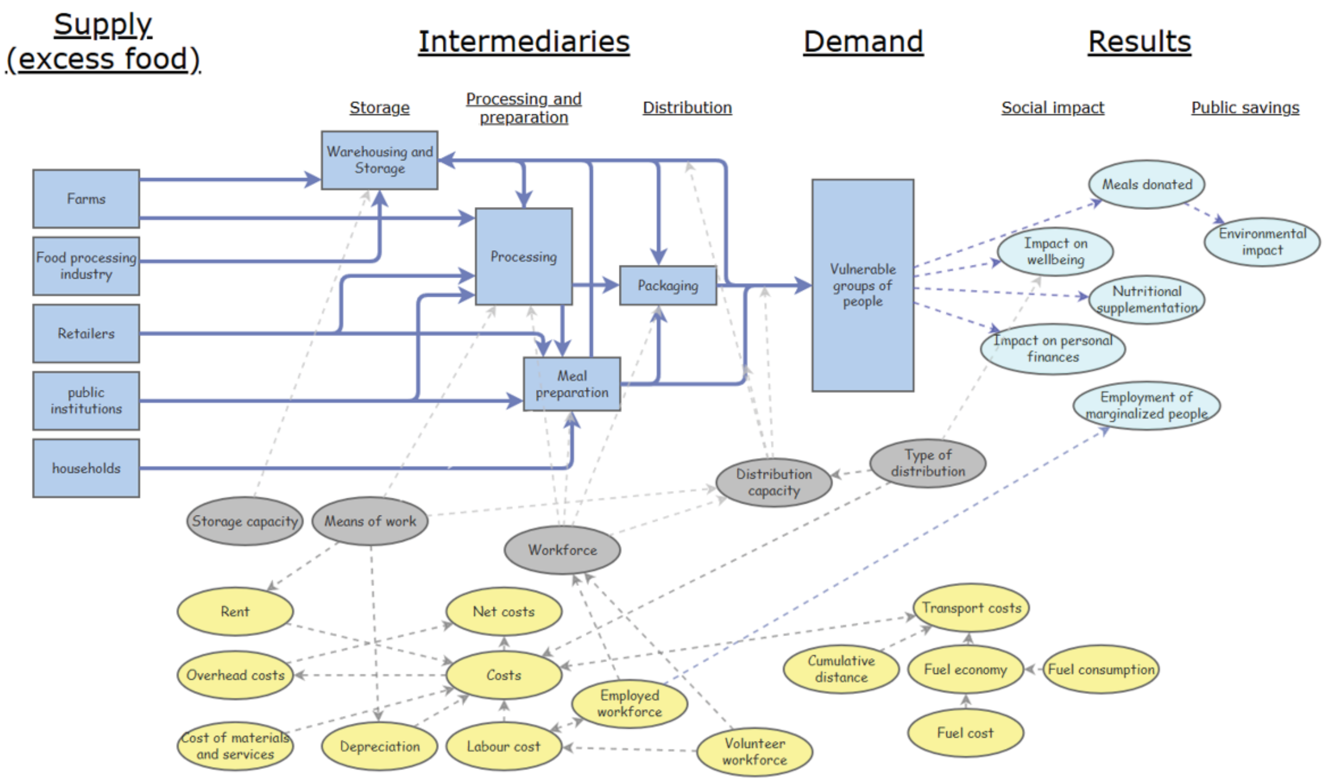

Figure 1. Causal loop diagram of the food redistribution process (Own elaboration)

During the modelling process we gathered several notable insights into food redistribution dynamics:

- The largest portion of surplus food (57% in this case) consists of unsold bread, which poses a challenge in providing nutritionally balanced meals.
- There is a strong seasonal variation in the supply of surplus food, impacting the consistency of re-distribution efforts.
- Food redistribution in a canteen setting, as opposed to a packaged donation, appears to provide additional social benefits, including fostering social cohesion and feelings of reciprocity among vulnerable populations. We aim to confirm this by surveying of beneficiaries of several different donation types.
- Discussions with Etri employees revealed regulatory limitations, such as contractual clauses limiting food donation among competitors.

We also consulted with Local Action Groups (LAGs), interviewing them on the following:

- Similar enterprises that could serve as additional data sources. We found that there is a lack of food redistribution enterprises utilising the same donation approach, however there are several that could serve as a control for establishing the impact on beneficiaries' well-being.
- The existence of projects with similar infrastructure requirements (food-safety certified kitchens and canteens). Our findings indicate that there were some projects including cooking classes for FLW reduction that utilised public infrastructure (i.e. local school's kitchen facilities).
- Their interest and need for the data support we are aiming to provide. They expressed interest in using the model for small-scale projects. We are currently in discussions with one such LAG for implementing the model in a call for proposals.

REFERENCES

Cattaneo, A., Federighi, G. and Vaz, S. (2021). The environmental impact of reducing food loss and waste: A critical assessment. Food Loss and Waste: Evidence for Effective Policies 98: 101890.

Coyle, R. G. (1997). System Dynamics Modelling: A Practical Approach. Journal of the Operational Research Society 48: 544–544.

Mayne, J. (2017). Theory of Change Analysis: Building Robust Theories of Change. Canadian Journal of Program Evaluation 32: 155–173.

Poczta-Wajda, A., and Guth, M. (2024). CHALLENGES TO HOUSEHOLD FOOD SECURITY – EXPERIENCES FROM EUROPEAN UNION COUNTRIES. Annals of the Polish Association of Agricultural and Agribusiness Economists XXVI: 189–200.

RUSTIK. (2025). Rustik. https://rustik-he.eu/

Statistics | Eurostat. (2025). https://ec.europa.eu/eurostat/databrowser/view/ilc_mdes03/default/table?lang=en

Driven to waste: The global impact of food loss and waste on farms. 2021. Retrieved 15 July 2025, from https://wwfeu.awsassets.panda.org/downloads/driven_to_waste_the_global_impact_of_food_loss_and_waste_on_farms.pdf

Use of LPIS Data to Estimate the Potentials for Valorisation of Agricultural By-products

Borut Stojilković[1], Stane Kavčič[2] and Luka Juvančič[2]

[1] Ministry of Higher Education, Science and Innovation, Masarykova cesta 16, Ljubljana, Slovenia
[2] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 110, Ljubljana, Slovenia, (luka.juvancic@bf.uni-lj.si)

ABSTRACT

This study explores the use of Land Parcel Identification System (LPIS) data to estimate the spatial potential for valorising agricultural by-products in Slovenia. By integrating LPIS crop and livestock data with residue generation coefficients, spatial biomass availability was calculated and classified using geospatial tools. Results highlight livestock excreta and cereal residues as the largest by-product streams, with significant variation in spatial concentration. Findings underscore the importance of localized, high-value valorisation strategies due to structural and logistical constraints. The approach offers a replicable method for supporting bioeconomy planning by addressing data gaps and informing efficient biomass collection and processing infrastructure development.

INTRODUCTION

The efficient collection of agricultural by-products for further valorisation by closing material and energy loops (eg. bioenergy, fertilizers and biostimulants, biobased materials) is shaped by a complex interplay of structural, logistical, and systemic factors. A key challenge lies in the dual farm structure prevalent across the EU, where small-scale farms coexist with large commercial operations (Eurostat, 2025). This fragmentation complicates scalable and cost-efficient the aggregation of residues such as straw, husks, and pruning waste (Lehtinen et al., 2021). Additionally, the seasonal and spatially dispersed nature of biomass generation, coupled with variability in moisture content and perishability, poses significant logistical hurdles (Socas-Rodríguez et al., 2021). Even in technologically advanced regions, the cost-effectiveness of collection is undermined by the need for timely harvesting, drying, and transport infrastructure. While Europe has made strides in developing bioeconomy markets and circular systems, the lack of reliable, granular data on by-product availability remains a critical bottleneck (ECA, 2022).

Agricultural statistics in the EU typically focus on primary production, offering limited insight into the volume, type, and location of by-products (Camia et al., 2018). This data gap hampers the design of efficient logistics and investment in processing infrastructure. A promising solution lies in leveraging administrative data, particularly the Land Parcel Identification System (LPIS), a geospatial database used under the EU's Common Agricultural Policy (CAP). LPIS provides detailed, parcel-level information on land use and crop types, which can be cross-referenced with residue generation coefficients to estimate spatial biomass availability (Bedoić et al., 2019). When integrated with agricultural production statistics and farm-level reporting, LPIS can support spatially explicit biomass mapping, enabling planners and processors to optimize collection routes, reduce costs, and ensure a steady supply of raw materials.

MATERIALS AND METHODS

Data acquisition and calculations were done in two parallel processes in the Microsoft Excel and Esri ArcMap environments. One process consisted of geospatial analyses of polygon layers with land use and crop data. The data for plant production was obtained from administrative data source, LPIS (Land Parcel Identification System), a digital map-based system used to identify and manage agricultural land eligible for CAP area-based payments. The data basis for estimating of the quantity of by-products in livestock production also came from the same administrative source, namely point layers of agricultural holdings reporting on live-stock status (AKTRP, 2023). Both processes have in common a final stage where we performed the final calculations on blocks of the same size and the classification of the results into five classes according to the Jenks method.

Layers of land use and crop data are vector polygonal in their original form. Layers for selected crops (wheat, barley, oats, triticale, spelt, rye) and plantations (apples) were converted into raster layers with a raster resolution of 1 m x 1 m in the first phase. In the next step, the Zonal Statistics tool was used to calculate the values of each zone by counting the individual cells and multiplying the latter by respective AWCB (Agricultural Waste, Co-products and By-products) indices (Bedoić et al., 2019) to obtain the quantities of by-products of crop production. In the final stage, the results were displayed by block [kg/block].

Table 1. Studied agricultural by-products and their AWCB indices

Element	Unit	Value in kg/m^2 or kg dry matter/m^2
Straw (barley)	kg dry matter/m^2	0.275
Straw (oats)	kg dry matter/m^2	0.250
Straw (wheat, triticale, spelt, rye)	kg dry matter/m^2	0.300
Spelt husks	kg dry matter/m^2	0.045
Apple prunings	kg dry matter/m^2	0.190
Sludge (dairy cows)	m3/ livestock unit	15
Sludge (beef cattle)	m3/ livestock unit	12
Sludge (pigs)	m3/ livestock unit	15

The layers of Livestock Unit (LU) coefficient values derived from animal weights (i.e. for pigs, beef cattle and dairy cows) were obtained by first performing the basic calculations with the condition that the livestock status exceeds the value of 10, and merging the data with the holdings layer, which is a vector point layer. In doing so, we applied the criterion that if, for example, the total Livestock Unit count from pig farming exceeded that from cattle farming (i.e. not only the total number of pigs exceeded the total number of cattle), we classified the individual holding as a pig farm. The others were assumed to be cattle farms (where they could also have poultry, small livestock, etc.), and within them, the classification was determined based on the secondary criterion of whether the total livestock status is dominated by cows or animals under two years of age. In the latter cases, farms were classified as fattening farms. The values of the strata according to the spatial unit were calculated using the Zonal Statistics tool and the totals were displayed by block.

The size of the blocks was determined in accordance with the principle of the critical logistics measure, which is the cost of transport, since for a larger distance than this, the value of the biomass does not bear the cost. Applying the estimated distance thresholds for cost-effective transport of agricultural biomass (Börjesson et al., 1996) to the context of (small and dispersed) landholding structure in Slovenia block size of 5 km x 5 km was determined.

The results of each element studied were classified by the Jenks method into five classes. The values of each class were displayed in the blocks where these elements are located. In the final stage, for each element studied (i.e. crop or value within each livestock unit category), we summed its values in the three classes above and calculated the proportion of the values of these three compared to the total value of all five classes. For this purpose, the geo-information data were exported to Excel, where the calculations of the proportions were carried out.

RESULTS

After performing the Jenks classification method, the results per bloc are distributed in five classes (Figure 1).

For each element (e.g. dairy cows), we calculated the proportion of the top three classes of the total sum of the block values of all five classes (Table 2).

Table 2. Estimated total quantity and spatial concentration of studied agricultural by-products

Studied agricultural by-products	Estimated quantity (units)	Estimated total quantity	Proportion of the sum of the values in the blocks in the upper 3 classes, %
Cereal straw	t	164,650	74.2
Spelt husks	t	274	47.6
Pruning residues	t DM	21,958	65.5
Apples (inferring apple pomace)	t	500	70.9
Dairy cows (inferring slurry)	t DM	336,505	67.5
Beef cattle (inferring slurry)	t DM	68,431	67.1
Pigs (inferring slurry)	t DM	26,569	42.1

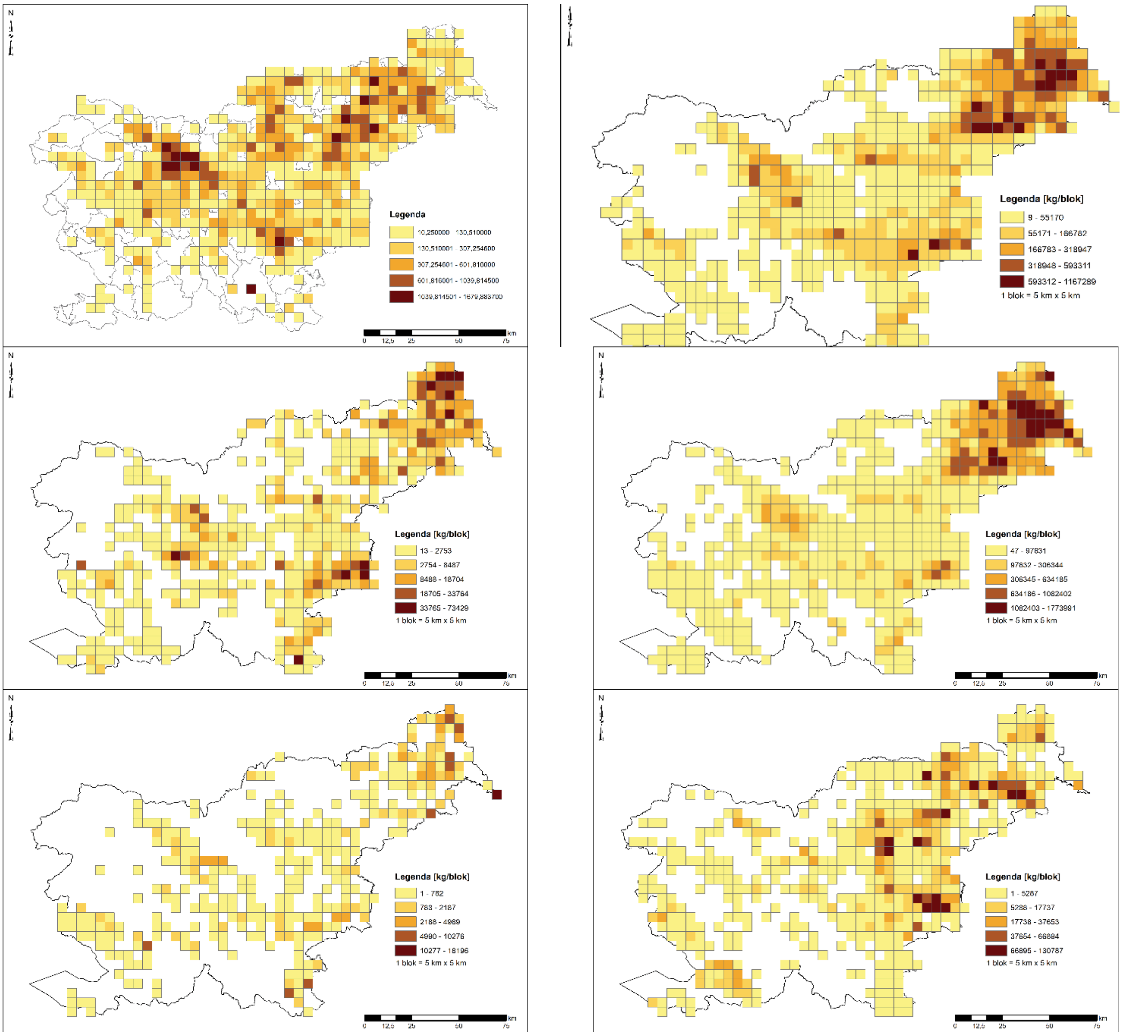

Figure 1. Spatial distribution of blocks in a specific class according to Jenks classification (dairy cattle (top left), barley (top right), oats (centre left), mixed crops (centre right), spelt (bottom left) and apples (bottom right).

DISCUSSION

By far the most extensive by-product of agricultural production in Slovenia is livestock excreta. In the context of their more efficient utilization, special attention is given to slurry, whose annual quantity amounts to approximately 500,000 tonnes of dry matter, with nitrogen losses due to improper fertilization exceeding 20% (Verbič, 2022). In addition to improved fertilization technology (which is not the subject of this contribution), there is also potential to improve management through the production of heat and electricity (and potentially biogas), as its current utilization is well below 10% of its potential. A relevant alternative is combining slurry management with the energy use of woody biomass (e.g., biochar, which enables carbon se-questration in soils). These improvements require significant investments and are therefore unattainable for most farms. However, the relatively favourable spatial concentration of slurry quantities suggests the relevance of collective investments in this area. To enable this, legal barriers in the area of fertilization must first be addressed, as the current regulation limits the application of processed manure (e.g., digestate) solely to the farmer's own land, thus excluding collective investments de facto. Among secondary crops and post-harvest residues, the residues from cereal harvesting stand out by quantity, with annual volumes amounting to approximately 300,000 tonnes of dry matter. There are various ways to add value to harvest residues: from niche products (e.g., building materials, packaging, growing substrates) to energy uses (heat, biofuels). Under the conditions in which Slovenian agriculture operates (low share of arable land, fragmented land use), it is reasonable to continue using most harvest residues to maintain soil organic matter balance. The dominant use (ploughing in, bedding) could be replaced by conservation practices, such as using residues as mulch. Only a few areas have sufficient spatial concentration and volume of residues; even there, niche strategies with high added value should be prioritized. In fruit production, in the context of closing material loops through the valorization of by-products or co-products, a key issue is their high water content and consequent perishability. Therefore, for their efficient further use, it is necessary either to enable rapid batch processing of the residues or to introduce various measures to extend the stability of agricultural by-products. A specific challenge here is the small quantities involved, which lead to difficulties in organizing processing and an unfavorable cost-to-price ratio. Their economic viability is thus limited to high-end niche products (e.g. food supplements, promotional packaging).

ACKNOWLEDGEMENT

The paper draws from the project "Circular technological concepts and business models in Slovenian agriculture", grant V4-2208, co-funded by Slovenian Research and Innovation Agency and Ministry of Agriculture, Forestry and Food.

REFERENCES

AKTRP. (2024). Spatially explicit data on crops (LPIS) and de-individualised farm-level data on agricultural production from summary applications from CAP Single Application Forms 2022. Agencija za kmetijske trge in razvoj podeželja, Ljubljana (unpublished dataset).

Bedoić, R., Ćosić, B. and Duić, N. (2019). Technical potential and geographic distribution of agricultural residues, co-products and by-products in the European Union. Science of the total environment 686: 568-579.

Börjesson, P. and Gustavsson, L. (1996). Biomass transportation. Renewable energy 9(1-4): 1033-1036.

Camia A., Robert N., Jonsson R., Pilli R., García-Condado S., López-Lozano R., van der Velde M., Ronzon T., Gurría P., M'Barek R., Tamosiunas S., Fiore G., Araujo R., Hoepffner N., Marelli L. and Giuntoli J. (2018). Biomass production, supply, uses and flows in the European Union. First results from an integrated assessment, Publications Office of the European Union, Luxembourg.

European Court of Auditors. (2022). Data in the Common Agricultural Policy - Unrealised potential of big data for policy evaluations. ECA Special report 16 (2022). https://www.eca.europa.eu/Lists/ECADocuments/SR22_16/SR_Big_Data_in_CAP_EN.pdf

Eurostat. (2025). Farms and farmland in the European Union – statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics

Lehtinen, U. and Ala-Rämi, K. (2021). Supply of Biomass and Agricultural Waste for Promoting Low-Carbon Business-Ecosystem, in: Bhat, R. (ed.): Valorization of Agri-Food Wastes and By-Products: Recent Trends. Innovations and Sustainability Challenges 899-912.

Socas-Rodríguez, B., Álvarez-Rivera, G., Valdés, A., Ibáñez, E., and Cifuentes, A. (2021). Food by-products and food wastes: are they safe enough for their valorization? Trends in Food Science & Technology 114: 133-147.

Verbič, J. (2022). Učinkovita raba živinskih gnojil. Kmetovalec 90(5): 3-7.

Sustainable Farming in Serbia – FADN Data Exploration

Mirela Tomaš Simin, Aleksandar Miljatović, Tihomir Novaković, Jelena Despotović, Danica Glavaš-Trbić and Marica Petrović

Faculty of Agriculture, University of Novi Sad, Trg Dositeja Obradovića 8, Novi Sad, Serbia, (mirela.tomas@polj.edu.rs)

ABSTRACT

This paper explores the economic, ecological, and social dimensions of sustainability in Serbian agricultural holdings, using FADN data as the primary source. The analysis shows that economic viability has improved overall, with notable regional disparities farms in Serbia North consistently outperforming those in the south. Sectoral differences were also evident, with horticulture and granivore farms achieving higher economic sustainability compared to dairy and grazing livestock farms. Ecological analysis focused on biodiversity revealed consistently low Shannon diversity index values on dairy farms, indicating limited crop diversity and highlighting the need for diversification. The study also addresses the social dimension of sustainability, emphasizing the lack of standardized indicators and the influence of farmers' experience, education, and gender on productivity and farm performance. These findings demonstrate the complexity of assessing farm sustainability and the importance of integrating economic, ecological, and social indicators. The results suggest that targeted support and tailored strategies are needed to enhance sustainability across all dimensions, especially in less developed regions and among vulnerable farm types.

INTRODUCTION

One of the earliest definitions of sustainability was introduced by Repetto, who argued that sustainability is grounded in the principle that present-day decisions must not jeopardize the potential for future generations to maintain or enhance their living standards (Repetto, 1985). Also, the widely accepted definition of sustainable development originates from the Brundtland Report (WCED, 1987), emphasizing development that meets present needs without compromising future generations. Harris (2009) expanded this view by suggesting that "the path to sustainable development is one where the overall stock of fixed assets is either stable or grows over time." Broadly speaking, sustainable development can be described as a process that seeks to harmonize diverse human activities with the capacity of the environment. Modern scientific and policy discourse generally agrees that sustainable development seen essentially as system sustainability arises from the interplay between ecological, economic, and social factors.

Measuring sustainability often relies on the use of indicators, which help connect theory with practice. Indicators condense complex data into more accessible forms that facilitate decision-making and inform policy. According to Bossel (1999), such indicators must be easy to interpret, transparent in their meaning for all involved parties regardless of educational background and based on information that can be gathered without excessive complexity or cost. Ideally, data collection should be straightforward enough to integrate into daily observation and routine analysis.

When applied to agricultural holdings, sustainable agricultural systems can be described as those that produce goods and services (economic role), steward natural resources carefully (ecological role), and foster the vitality of rural communities (social role) (Diazabakana et al., 2014). A thorough evaluation of all sustainability dimensions is vital for ensuring the future progress of agricultural holdings. In line with this, a project funded at the Faculty of Agriculture in Novi Sad, Serbia was launched with the aim of assessing these indicators, and the purpose of this paper is to present some of the results obtained through this research. The FADN database was adopted as the basis for this analysis because it fulfils the key requirements for indicator selection outlined above. The Farm Accountancy Data Network (FADN) is the main European source of microeconomic data for agricultural holdings, aimed at evaluating farm income and business performance. Although primarily focused on economic data, FADN offers indirect insight into ecological and limited social factors. The European Union has recognized the limitations of the FADN system, particularly its strong focus on the economic dimension while largely neglecting the social and ecological aspects in the assessment of farm sustainability. As a result, a transition is currently underway from the FADN to the more comprehensive FSDN (Farm Sustainability Data Network), which aims to address these shortcomings.

The first research question in the project and this paper focused on identifying sustainability indicators that can be derived from the FADN database, which is presented in the paper through the tables 1, 4 and 6. Subsequently, further research was conducted to assess selected indicators, as shown in the tables 2, 3 and 5.

MATERIAL AND METHODS

Sustainability indicators for agricultural holdings were selected based on peer-reviewed international and domestic publications. Relevant keywords were used to search databases such as SCOPUS, Google Scholar, and ScienceDirect, covering economic, environmental, and social aspects of sustainability. When analysing the reviewed papers, the most frequently used economic indicators were ROA, ROE, and LTEV; ecological indicators often included biodiversity proxies like the Shannon Index; while social indicators remained scarce and inconsistent (Miljatović et al., 2025; Despotović et al., 2024). The analysis focused on Serbian family farms included in the FADN sample from 2015 to 2021, specifically those present throughout the entire seven-year period. After excluding farms with extreme values or missing data, the final sample included 527 holdings.

Economic viability of farms was evaluated as the ratio of farm net income (FNI) and reference income (RI). Farm net income is calculated as the following (EC, 2022):

$$FNI = TO - IC + BCST - D + BSTI - EF$$

where TO is the total output, IC is the total intermediate consumption, BCTS is the balance of current subsidies and taxes, D is depreciation, BSTI is the balance of subsidies and taxes on investment, and EF is the total external factors (which are not the property of the farm: wages paid, rent paid, interest paid). Reference income represents the sum of oppotunity costs of own factors of production (labour, non-land capital and land). Opportunity cost of labour is the product of hourly average wage in national economy and the unpaid labour (family labour) hours for a year (O'Donoghue et al., 2016; Kołoszycz, 2020). Opportunity cost of non-land capital is the product of total equity minus value of agricultural land of the farm and the 5% rate of return (Frawley and Commins, 1996; Hennessy and Moran, 2015). Opportunity cost of land is the product of hectares of own land and average land rent in specific region (Coppola et al., 2020).

Share of economically viable farms (SEV) is estimated as the following ratio:

$$SEV = \frac{the\ number\ of\ farms\ where\ FNI\ \geq\ RI}{total\ number\ of\ farms\ in\ the\ sample}$$

For LTEV calculation farms were categorized by type of farming into: (1) specialist field crops, (2) specialist permanent crops (vineyards and fruits), (3) specialist milk, (4) specialist grazing livestock (cattle, sheep, goats), and (5) mixed farms representing around 96% of all commercial farms in Serbia.

Economic viability was assessed using the opportunity cost approach, with a focus on long-term economic viability (LTEV), as it fully accounts for the opportunity costs of labor, capital, and land the three key agricultural production factors (Hlavsa at el., 2020). The formula used to calculate economic viability is as follows:

$$LTEV = \frac{FNI}{TOC}$$

where FNI represents farm net income and TOC stands for total opportunity costs. Farms with an LTEV coefficient of 1 or higher are considered economically viable, as they use their resources efficiently and earn more from farming than they would by reallocating their production factors elsewhere. In contrast, farms with an LTEV below 1 cannot generate enough net income to cover the opportunity costs of their own resources, indicating insufficient profitability or a net loss (Miljatović et al., 2025).

The formula for calculating the Shannon Diversity Index is:

$$H' = -\sum_{\infty}^{s}(pi) * (lnpi)$$

Where: H' = Shannon diversity index; S = number of species in the area; pi = proportional share of the i-th species in the total area of all observed species, ln = natural logarithm.

For agricultural holdings, the Shannon index measures crop diversity and distribution as the absolute sum of each crop's share in total cultivated area multiplied by its natural logarithm. The Shannon index can be used to assess biodiversity in plant, animal, and microbial species, both above and below ground, as well as in aquatic environments (Ortiz-Burgos, 2016).

Given the aforementioned limitations of the FADN database with regard to social indicators, this paper presents only the potential indicators available within the database that could possibly be used for assessing the social sustainability of agricultural holdings.

RESULTS AND DISCUSSION

Economic indicators of farm sustainability

In the initial phase of our research, we first identified a set of potential economic sustainability indicators that could be extracted from the FADN database (Table 1). The aim was to establish a foundation of relevant indicators, some of which would later be applied in the assessment of farm economic viability. Defining the economic sustainability of agricultural holdings can be challenging. Savickiene et al. (2015) describe it effectively as "the ability of a farm to survive, live, and develop using available resources." Indicators for assessing economic sustainability largely rely on the FADN system, originally designed to monitor production and economic performance at the farm level. According to Latruffe et al. (2016b), the main economic indicators fall into four categories: profitability, liquidity, stability, and productivity. Table 1 presents the indicators that the authors considered potentially relevant for evaluating economic sustainability based on their theoretical significance and data availability within the FADN system.

Table 1. Potential Economic Sustainability Indicators Derived from FADN Data

Indicator group	Indicators	
FINANCIAL SUSTAINABILITY	Profitability	Return on Assets (ROA)
		Return on Equity (ROE)
		Return on Invested Capital (ROIC)
		Return on Sales (ROS)
	Liquidity	Working Capital to Short-Term Liabilities Ratio
		Total Liabilities to Net Cash Flow Ratio
	Stability	Debt to Equity Ratio
		Share of Fixed Assets in Total Assets
		Equity to Fixed Assets Ratio
PRODUCTIVITY	Partial Productivity	Value of Production per Annual Work Unit
		Value of Production per Agricultural Land Used
		Gross Profit per Annual Work Unit
		Gross Profit per Agricultural Land Used
		Net Added Value per Annual Work Unit
		Net Added Value per Agricultural Land Used
		Net Profit per Annual Work Unit
		Net Profit per Agricultural Land Used
		Net Profit per Family Member
	Total Productivity	Technical Efficiency (TE)
		Total Factor Productivity (TFP)
		Opportunity Cost Approach

Source: Authors

After identifying the potential indicators, the subsequent phases of the research focused on evaluating a selection of these indicators, with the results of these assessments presented in the following sections.

In our research, we performed various calculations following the described methodology, which led to several important findings. The results indicate that the share of economically viable farms in Serbia increased significantly over the observed seven-year period (Miljatović et al., 2024). By 2021, 59.4% of farms were economically viable 20.4 percentage points more than in 2015 (Figure 1). In the past four years, this share remained at or above 50%, indicating that over half of the farms were economically sustainable. Farms in the Serbia North region consistently outperformed those in the Serbia South region; in the North, the share of viable farms was above 50% almost throughout the entire period, peaking at 77.2% in 2021. In contrast, the South saw rates consistently below 50%, highlighting substantial challenges to achieving economic viability likely due to lower levels of agricultural development driven by poorer climate conditions, limited human resources, and inadequate technical equipment.

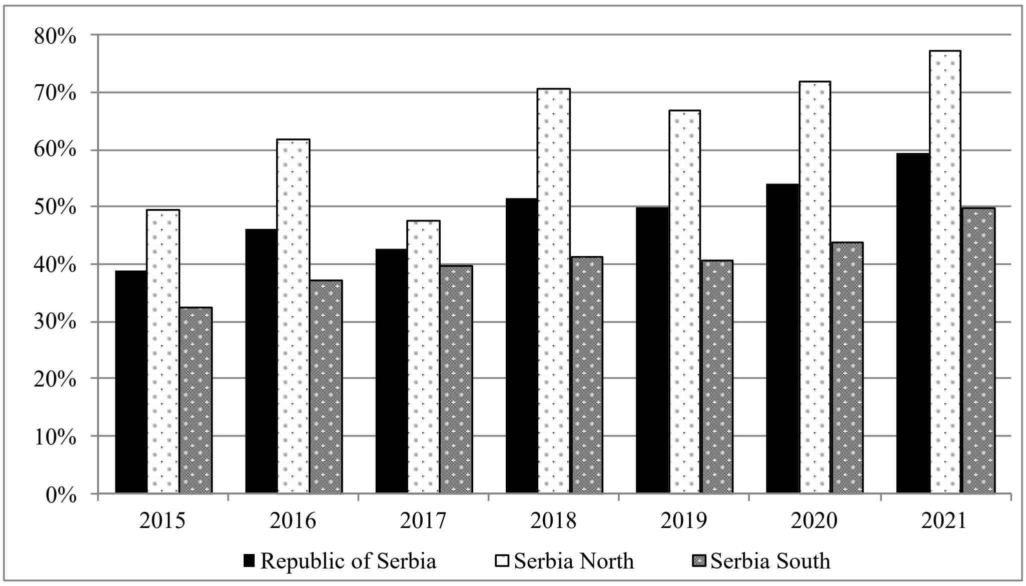

Figure 1. Share of economically viable farms from 2015 to 2021

Source: Authors

The analysis by type of farming revealed that horticulture and granivore farms had the highest shares of economically viable holdings, at 66.5% and 65.5% respectively (Table 2). These farms demonstrated high asset turnover. As noted by Coppola et al. (2022), granivore farms, due to their production processes, operate similarly to industrial systems. This can be attributed to their relatively short production cycles a feature also common in horticulture, where multiple crops can be grown in a season thanks to brief vegetation periods. This faster production leads to better economic performance. Conversely, farms specializing in other grazing livestock had the lowest share of viable holdings, at just 35.6%, with even worse results in Serbia South, where only 33.8% were economically sustainable. These findings align with Hloušková et al. (2022), who reported that grazing livestock farms were the least economically viable in the Czech Republic.

Table 2. Share of economically viable farms by type of farming, 2015-2021

TF 8	Type of farming	Share of economically viable farms (%)		
		Republic of Serbia	Serbia North	Serbia South
[1]	Fieldcrops	58.6	65.6	44.1
[2]	Horticulture	66.5	65.3	66.9
[3]	Wine	52.4	33.3	60.3
[4]	Other permanent crops	52.8	64.4	48.5
[5]	Milk	41.8	73.8	36.8
[6]	Other grazing livestock	35.6	49.6	33.8
[7]	Granivores	65.5	70.0	63.5
[8]	Mixed	42.5	59.7	35.8
	Total	49.8	64.7	41.4

Source: Authors

In another part of our research, we evaluated the long-term economic viability (LTEV) indicator as a measure of overall farm sustainability (Miljatović et al., 2025). The LTEV demonstrated positive values throughout the analysed period, with average coefficients exceeding one across all farming types indicating that farms were able to cover the opportunity costs of production factors from their net income (Table 3). As expected, results varied by farming type: field crop farms recorded the highest LTEV value (2.91), while grazing livestock farms had the lowest (1.03). Overall, livestock farms demonstrated lower average economic viability coefficients compared to crop farms, consistent with findings from a Czech study (Hlavsa at el., 2020).

Table 3. Descriptive statistics of the LTEV indicator for various types of farming

Descriptive statistics	Field crops	Permanent crops	Milk	Grazing livestock	Mixed
Mean	2.91	2.49	1.60	1.03	1.30
Median	1.59	1.44	0.96	0.68	0.85
Lower Quartile	0.37	0.49	0.50	0.16	0.36
Upper Quartile	4.16	3.39	1.75	1.40	1.82
Standard Deviation	5.35	3.88	2.44	2.03	1.53
n	254	48	103	56	66
T	7	7	7	7	7
N	1778	336	721	392	462

Source: Miljatović et al., 2025.

As expected, the median values of the observed indicator are lower, highlighting the significantly reduced economic viability of farms in Serbia. The situation is especially concerning for milk, mixed, and grazing livestock farms, where the median coefficient falls below one. Grazing livestock farms are the most at risk, consistent with Hloušková et al. (2022) they show the lowest average and median economic viability coefficients and consistently have less than 50% of farms classified as economically viable.

Ecological and social indicators of farm sustainability

As with the economic dimension, the initial phase of the research also aimed to identify potential ecological and social indicators that could be derived from the FADN database. Although FADN is primarily designed to capture economic data, its structural and production-related components provide a basis for extracting certain environmental and social indicators. Table 4 presents a set of ecological indicators that the authors considered potentially relevant for assessing environmental sustainability, based on data availability and alignment with established frameworks. The environmental impacts of agriculture are often difficult to measure directly (Bockstaller et al., 2008). Over the past 35 years, numerous agro-ecological indicators have been developed to assess negative effects on water, air, soil, biodiversity, greenhouse gas emissions, and other environmental issues associated with farming. The OECD was among the first to propose such indicators (Spânu et al., 2022), defining them as summary measures that combine data to describe environmental conditions, risks, changes, and pressures partly or fully caused by agriculture. These indicators are commonly structured according to the Pressure-State-Response (PSR) model. While FADN primarily targets economic performance, its supplementary data allow for indirect insight into environmental pressures and responses (Table 4).

Table 4. Potential Environmental Sustainability Indicators Derived from FADN Data

PSR Concept	Indicators
Pressure	Livestock density
Pressure	Greenhouse gas emissions
Pressure	Use of mineral fertilizers
Pressure	Use of pesticides
Pressure	Water usage
Pressure	Energy usage
Response	Environmentally friendly practices (e.g., organic farming, subsidies for agro-environmental measures)
Pressure-State	Biodiversity
State-Response	Area of legumes
Pressure-State	Area of pastures and meadows

In the subsequent phases of the research, the assessment of ecological sustainability was conducted using a selected indicator – Shannon Diversity Index. One of the focuses of our study was dairy farms. The results showed that, on average, during the period from 2015 to 2021, dairy farms had low biodiversity. The Shannon diversity index did not exceed 2.5 for any farm in any observed year (Table 5). Moreover, dairy farms grew only a small number of crop types, with uneven distribution across cultivated areas. Typically, Shannon index values range from 1.5 to 3.5, rarely exceeding 4.5 (Ortiz-Burgos, 2016). Therefore, the biodiversity of dairy farms, measured by the presence and diversity of cultivated crops, can be considered extremely low.

Table 5. Shannon Diversity Index

Year	Mean value ± standard deviation	Minimum	Maximum	Number of farms with monoculture
2015	1.14±0.49	0	1.93	10
2016	1.16±0.48	0	2.11	7
2017	0.84±0.40	0	1.59	9
2018	1.16±0.47	0	1.87	8
2019	1.16±0.47	0	1.80	8
2020	1.14±0.45	0	1.80	8
2021	1.13±0.45	0	1.94	7
Average	1.10±0.47	0	2.11	8.14

Source: Despotović et al., 2024.

For the 49 dairy farms analysed, the average biodiversity rate measured by the Shannon index decreased by 2.93%. Five farms showed no change in biodiversity during the period, while 40 farms recorded an average annual increase of 2.65% from 2016 to 2021. The remaining farms had at least one year of monoculture (Shannon index value of 0), preventing calculation of chain indices and average annual change rates for these holdings.

When it comes to the social dimension of farm sustainability, Janker and Mann (2020) point out that clear indicators or measurement tools are still lacking. Many authors (Binder et al., 2010) emphasize that the social aspect has been largely neglected in research and continues to lag behind the economic and ecological dimensions. In the context of this study, only a potential list of social sustainability indicators was identified based on available FADN data, while their actual evaluation has not yet been carried out due to significant methodological limitations and data constraints. This highlights the complexity of assessing social sustainability and suggests that more comprehensive data such as that anticipated in the forthcoming FSDN system may be better suited for such assessments. Although some frameworks have been proposed to make the concept of social sustainability more operational, there is still no consensus on what this dimension should encompass or how it should be measured. Key questions remain regarding how policymakers, researchers, and stakeholders define the social aspect and how it can be translated into concrete, measurable indicators.

Table 6. Potential Social Sustainability Indicators Derived from FADN Data

Indicator Group	Indicators
Field	Age of the farm holder
	Age of the farm manager
Work Experience	Experience of the farm holder
	Experience of the farm manager
Agricultural Training	Practical experience
	Basic training
	Full training

Coppola et al. (2020) emphasize that farmers' work experience is vital, as more experienced producers are likely to make better decisions, positively affecting their farms' economic sustainability. Some researchers (Seok et al., 2018) connect this experience with the age of farm decision-makers. Education and training levels can also influence producers' innovativeness and productivity. Additionally, studies suggest that farm productivity may differ based on the gender of the owner or manager (Udry et al., 1995; Doss and Morris, 2000).

CONCLUSIONS

This study highlights the complexity of assessing agricultural sustainability and the importance of simultaneously considering economic, ecological, and social dimensions. The findings reveal pronounced regional and sectoral disparities in economic viability, with dairy and grazing livestock farms facing particular challenges. Ecological analysis, based on the Shannon diversity index, pointed to low biodiversity on dairy farms, underscoring the need for diversification to strengthen environmental resilience. Regarding the social dimension, only a preliminary set of potential indicators could be identified due to limitations in the FADN database, emphasizing the need for more suitable data frameworks, such as the forthcoming FSDN. Overall, the results support the use of integrated, multidimensional assessment approaches and point to the need for better-aligned data systems and targeted policy measures to promote sustainable development of agricultural holdings in Serbia.

ACKNOWLEDGEMENT

This research was funded by the Science Fund of the Republic of Serbia, grant number: 10843, project title: Farm Economic Viability in the context of Sustainable Agricultural Development ViaFarm.

REFERENCES

Binder, C., Feola, G. and Steinberger, J. (2010). Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture, Environmental Impact Assessment Review 30(2): 71-81.

Bockstaller, C., Guichard, L., Makowski, D., Aveline, A., Girardin, P. and Plantureux, S. (2008). Agri-environmental indicators to assess cropping and farming systems. A review. Agronomy for Sustainable Development 28(1): 139–149.

Bossel, H. (1999). Indicators for Sustainable Development: Theory, Method, Applications. A Report to the Balaton Group. International Institute for Sustainable Development. Winnipeg, Canada.

Coppola, A., Scardera, A., Amato, M. and Verneau, F. (2020). Income levels and farm economic viability in Italian farms: An analysis of FADN data. Sustainability 12(12): 4898.

Coppola, A., Amato, M., Vistocco, D. and Verneau, F. (2022). Measuring the economic sustainability of Italian farms using FADN data. Agric. Econ. 68: 327–337.

Despotović, J., Novaković, T., Miljatović, A., Glavaš-Trbić, D., Tomaš Simin, M. and Petrović, M. (2024). Biodiverzitet na gazdinstvima za proizvodnju mleka. Agroekonomika 53(104): 47-56.

Diazabakana, A., Latruffe, L., Bockstaller, C., Desjeux, Y., Finn,J., Kelly, E., Ryan, M. and Uthes, S. (2014). A Review of FarmLevel Indicators of Sustainability with a Focus on CAP and FADN. Deliverable 1.2 of the EU FP7 project FLINT.

Doss, R. and Morris, L. (2000). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural economics 25(1): 27-39.

Frawley J.P., Commins P. (1996). The Changing Structure of Irish Farming: Trends and Prospects. Rural Economy Research Series No. 1, Teagasc.

Harris, J. (2009). Economics of Environment and Natural Resources - Contemporary Approach, Datastatus, Belgrade.

Hennessy T. and Moran B. (2015). The viability of the Irish farming sector in 2015. Teagasc.

Hlavsa, T., Spicka, J., Stolbova, M. and Hlouskova, Z. (2020). Statistical analysis of economic viability of farms operating in Czech areas facing natural constraints. Agric. Econ. 66: 193–202.

Hloušková, Z., Lekešová, M., Prajerová, A. and Doucha, T. (2022). Assessing the Economic Viability of Agricultural Holdings with the Inclusion of Opportunity Costs. Sustainability 14(22): 15087.

Janker, J. and Mann, S. (2020). Understanding the social dimension of sustainability in agriculture: a critical review of sustainability assessment tools. Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development 22(3): 1671-1691.

Kołoszycz, E. (2020). Economic viability of dairy farms in selected European Union countries. Annals PAAAE 22(3): 129-139.

Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E., Ryan, M. and Uthes, S. (2016). Measurement of Sustainability in Agriculture: A Review of Indicators. Studies in Agricultural Economics 118(3): 123–130.

Miljatović, A., Tomaš Simin, M., Novaković, T. and Vukoje, V. (2024): Assessment of economic viability and income gap of Serbian farms, AGROFOR International Journal 9(3): 77-84.

Miljatović, A., Tomaš Simin, M. and Vukoje, V. (2025). Key Determinants of the Economic Viability of Family Farms: Evidence from Serbia. Agriculture 15(8): 828.

O'Donoghue, C., Devisme, S., Ryan, M., Conneely, R., Gillespie, P. and Vrolijk, H. (2016). Farm Economic Sustainability in the European Union: A Pilot Study. Studies in Agricultural Economics 118(3): 163–171.

Ortiz-Burgos, S. (2016). Shannon-Weaver Diversity Index. In: Kennish, M.J. (eds) Encyclopedia of Estuaries. Encyclopedia of Earth Sciences Series. Springer, Dordrecht.

Reppeto, R. (1985). The Global Possible-Resources, Development and New Century. World Resources Institute Book, Yale University Press, New Haven.

Savickienė, J., Miceikienė, A. and Jurgelaitienė, L. (2015). Assessment of economic viability in agriculture. Proceedings of the Strategica International Academic Conference "Local versus Global", Bucharest, Romania, 29-30 October 2015, 411-423.

Seok, H., Moon, H., Kim, G. and Reed, R. (2018). Is aging the important factor for sustainable agricultural development in Korea? Evidence from the relationship between aging and farm technical efficiency. Sustainability 10(7): 2137.

Spânu, I.A., Ozunu, A., Petrescu, D.C. and Petrescu, R.M. (2022). A Comparative View of Agri-Environmental Indicators and Stakeholders' Assessment of Their Quality. Agriculture 12(4): 490.

Udry, C., Hoddinott, J., Alderman, H. and Haddad, L. (1995). Gender differentials in farm productivity: implications for household efficiency and agricultural policy. Food policy 20(5): 407-423.

WCED (World Commission on Environment and Development). (1987). Our Common Future. Oxford University Press, Oxford, UK.

Assessment of Vegetable Production in Ljubljana, Capital of Slovenia

Tanja Travnikar, Matej Bedrač and Barbara Zagorc

Agricultural Institute of Slovenia, Agricultural Economics Department, Hacquetova ulica 17, Ljubljana, Slovenia, (tanja.travnikar@kis.si)

ABSTRACT

With Ljubljana's growing population, the question of how much food can be produced within the city is becoming increasingly important. Effective development of local policies on urban agriculture, sustainable supply chains, and food security requires a clear understanding of the current situation. However, data on self-sufficiency levels for specific agricultural products at the municipal level are not supported by appropriate models or analyses. The aim of this paper was therefore to develop a model and apply a methodological approach to assess the volume of production and the level of self-sufficiency in fresh vegetables in the Municipality of Ljubljana. Based on an adapted national model of production and consumption balances for agricultural products, we estimated average vegetable production for the period 2019–2023. The findings show that Ljubljana achieves around 22% self-sufficiency rate in fresh vegetables, which is below the Slovenian average (56%). The model relies on official data and does not include non-market production from household and community gardens, which supplement local supply but remain unassessed due to data gaps. The findings can serve as a professional basis for developing local policies and measures supporting urban agriculture and local food supply.

INTRODUCTION

Urban agriculture is a modern agricultural practice that encompasses crop cultivation as well as the livestock farming within urban areas with the aim of providing fresh food for the urban population. A key element of urban agriculture is the efficient use of limited urban areas, such as green areas, balconies, rooftops, and abandoned or degraded land, both within city centers and on their outskirts (De Bon et al., 2010; Teoh et al., 2024). Urban agriculture thus also includes farms located on the outskirts of cities that provide food to urban residents and offer various additional services, such as agritourism and the sale of local products (EFUA H2020, 2025). In Slovenia's capital city, Ljubljana, food production on agricultural land remains the dominant form of food provision, with the majority of locally produced food coming from agricultural holdings within the municipality (SRP MOL 2021–2027, 2020). Among crops, vegetable production is the most widespread in urban areas, primarily due to its suitability for small-scale cultivation and high demand for fresh vegetables in urban environments (Orsini et al., 2013; Edmondson et al., 2019).

This form of agricultural production provides numerous benefits, notably improved food security and public health, support for the local economy, social integration, and environmental sustainability. Due to relatively short supply chains, farms on the urban periphery have a competitive advantage over more distant suppliers, contributing to more efficient food provisioning for urban centers (Orsini et al., 2013; EFUA H2020, 2025). Many farms sell their products directly at farmers' markets or through on-farm stores, often complemented by additional activities such as agritourism, food processing, and similar.

Urban agriculture is globally widespread and includes a broad range of agricultural systems, from traditional practices to the most advanced technological approaches. It is estimated that between 25% and 30% of the global urban population is engaged in the agri-food sector (Orsini et al., 2013). Given the rapid trends of urbanization and the growing share of the urban population, which reached 55% of the world population in 2020 and is projected to rise to 60% by 2030 and 70% by 2050 (World Population, 2008), the development of urban food production is increasingly promoted. Following these global trends, data for Ljubljana also indicate continuous population growth (Rebernik, 2004; SURS, 2025).

Since 1945, Ljubljana has experienced dynamic population growth, primarily due to intense migration from rural and less developed areas of Slovenia and the former Yugoslavia. The population of the City Municipality of Ljubljana increased from 123,000 in 1948 to 265,000 in 1981 (Rebernik, 1999). After this period, a policy of polycentric development encouraged the growth of smaller urban and rural areas, thereby slowing migration to cities. As a result, Ljubljana's population growth slowed after 1981, but the city has remained a destination for newcomers. In 2024, the municipality had 297,575 residents, which is 12% more than in 1981 (SURS, 2025). The municipality includes 892 agricultural holdings, mostly located on its outskirts (SRP MOL 2021–2027, 2020). Over the past five years, their number has remained relatively stable despite strong pressures for changes in agricultural land use. These agricultural holdings cultivate just over 11,400 hectares of agricultural land, approximately half of which lies within the municipal boundaries. There are 399 farms with all their agricultural land located entirely within the municipality. About 2,400 hectares of arable land are found within Ljubljana, with around 10% of these areas used for vegetable production. Most vegetables are grown outdoors, with a smaller share produced in protected spaces.

The aim of this paper is to present a methodological approach for estimating the self-sufficiency level of fresh vegetables, using an adapted version of the national model (agricultural production and consumption balances), tailored to the available statistical data for the Municipality of Ljubljana. This represents an innovative approach, as no model for assessing vegetable production and self-sufficiency levels has previously been applied at the municipal level in Slovenia. The obtained results on the vegetable production in Ljubljana can serve as a professional basis for developing strategies to support and strengthen the potential of urban food production beyond traditional farming systems, including household gardens, community gardens, and cultivation on balconies and rooftops. Comprehensive knowledge of the current situation is a crucial foundation for targeted planning of future urban agriculture measures.

MATERIAL AND METHODS

There are several possible approaches to estimating vegetable production in the Municipality of Ljubljana. In this paper, however, we present a method based on adapted national production and consumption balance models. Data on production and consumption balances of agricultural products, including vegetables, are collected and compiled at the national level on an annual basis. The Agricultural Institute of Slovenia is responsible for preparing these balances. The models used are based on Eurostat methodology; detailed descriptions of the models can be found in the official documents: Manual to Compile Supply Balance Sheets, Vegetables, 1998, and Production and Consumption Balances of Agricultural Products, 2023. All data come from the Statistical Office of the Republic of Slovenia (SURS). The main data inputs include annual production figures for each agricultural commodity and detailed monthly foreign trade data (imports/exports), from which domestic consumption can be calculated. Based on domestic production and consumption requirements, the self-sufficiency rate is also determined. The model results produced by the Agricultural Institute are submitted to SURS, where the key indicators are used for various purposes such as monitoring market trends, analyzing the structure and development of individual markets, and supporting agro-economic decision-making. One useful and commonly used indicator is the self-sufficiency rate, which shows the extent to which domestic production can cover domestic consumption in the country. A self-sufficiency rate below 100% indicates a deficit and a need for imports, while values above 100% represent a surplus or export potential.

For this study, adapted national models were developed, taking into account the vegetable production areas and the population size within the municipality of Ljubljana. The entire municipal area (275 km^2) was considered, not only the settlement of Ljubljana (164 km^2). All other input data, such as losses, processing, imports, exports, and other factors, are based on national averages, as such data are not available at the municipal level.

Calculations are based on a five-year average of the most recent available final data (period 2019–2023). Theoretical assumptions about the structure of vegetable production areas in the municipality of Ljubljana (%) and average yields (t/ha) for individual vegetable types, both in open fields and protected spaces, are taken from national averages (see Figure 1). Only those vegetable types for which official yield data exist and which represent at least 1% share in the structure of vegetable production areas were included in the models. Data from long-term series at the Agricultural Institute of Slovenia (KIS) and own calculations based on annual crop production monitoring were also used. Based on these criteria, the model includes 19 different types of vegetables. Strawberries and potatoes were excluded as they are not classified as vegetables and therefore are not part of the national production and consumption balance models for vegetables.

The production and consumption balance model for fresh vegetables grown in open fields includes 19 vegetable types, which together represent 86% of the total vegetable production in open fields. According to SURS data, the area of open fields in the municipality of Ljubljana dedicated to vegetable production is estimated at 274 hectares. Production volume was estimated based on national average yield coefficients, including both market and non-market production (separated by vegetable type and for the group other fresh vegetables).

The model for production in protected spaces includes 17 vegetable types, which together represent 92% of the total vegetable production in protected spaces. According to data, the area of protected spaces dedicated to vegetable production in the municipality of Ljubljana is 16.1 hectares. Production volume was estimated using national average yields for market production in protected spaces (separated by vegetable type and for the group other fresh vegetables).

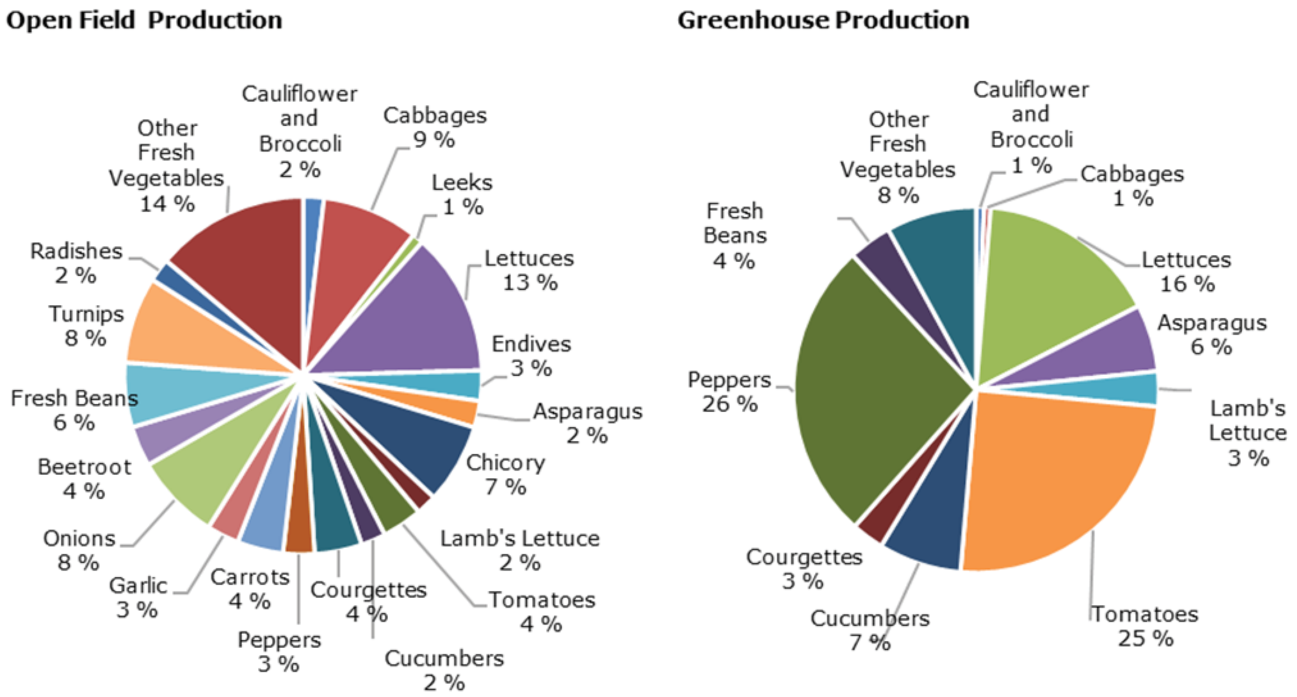

Figure 1. Structure of vegetable production in open fields and protected spaces (%; average 2019–2023)

Source: SURS, KIS databases, KIS calculations

Using this approach, production volumes (in tons) of vegetables were calculated separately for open fields and protected spaces for the municipality of Ljubljana. In further calculations, instead of the entire population of Slovenia, only the population of the municipality of Ljubljana was considered, calculated as a five-year average for the period 2019–2023. Population data are sourced from SURS.

RESULTS AND DISCUSSION

The results of the production and consumption balance of fresh vegetables grown in open fields show that the average annual production of vegetables on fields in the Municipality of Ljubljana during the period 2019–2023 was approximately 4,800 tons, which corresponds to 16.4 kg of fresh vegetables per capita. In the same period, the average annual production of vegetables in protected spaces was just under 1,000 tons, amounting to 3.4 kg per capita. The total annual agricultural production of fresh vegetables in the Municipality of Ljubljana thus amounts to approximately 5,800 tons or 19.8 kg per capita (Table 1). For comparison, the average fresh vegetable production per capita in Slovenia during the same period was 50.4 kg annually.

For assessing food security, the self-sufficiency rate is a more relevant indicator than the volume of production per capita, as it incorporates losses, processing, imports, exports, and other factors. The adjusted national food balance models indicate that the self-sufficiency rate for fresh vegetables in the Municipality of Ljubljana during 2019–2023 was 22.2%, while on the national level it was 55.6% in the same period. This means that Ljubljana reaches roughly 40% of the Slovenian average in terms of fresh vegetable self-sufficiency. The results focus on a five-year average; however, annual vegetable production is strongly dependent on weather conditions and fluctuated on the national level from 47% in 2023 to 61% in 2020 (Green report 2023, 2024).

Table 1. Vegetable production (average 2019–2023).

	Production (tone)	Fresh vegetables (kg per capita)	Self-sufficiency rate for fresh vegetables (%)
Slovenia	106,050	50.4	55.6
Municipality of Ljubljana	5,819	19.8	22.2

When interpreting these results, it is important to emphasize that the model, like the national model, covers only agricultural production. While this is the main source of food production and supply for urban areas, in the context of urban agriculture it would be beneficial to also assess the quantities of vegetables grown in household gardens, which in urban environments like Ljubljana can represent an important but under-researched source of local self-sufficiency (Vadnal et al., 2010). Numerous studies have shown that vegetable production in household gardens and other urban areas can significantly contribute to fulfilling the nutritional demands of urban populations (Bengtsson and Haller, 2025; Hume et al., 2021; CoDyre et al., 2014).

A literature review revealed that many studies address food production in household and community gardens (Bengtsson and Haller, 2025; Algert et al., 2014; Ghosh, 2021; Hume et al., 2021; Saha and Eckelman, 2017), mostly focusing on estimating production potential (i.e., possible vegetable production based on assumptions and average yields and/or GIS analyses) or empirical monitoring of actual yields compared to conventional production. However, we did not find approaches evaluating the production or potential of urban agriculture using national models such as agricultural production and consumption balances.

In the context of urban agriculture, a comprehensive assessment of local food supply requires including all sources of production, including self-supply from household and community gardens (Bengtsson and Haller, 2025; Gittleman et al., 2012). Despite growing interest in urban agriculture and the importance of self-sufficiency potential in cities, this field remains under-researched and lacks comprehensive data. Currently, there is a lack of systematically collected data and appropriate methodological approaches to monitor and evaluate production on these smaller but potentially important areas. Similar findings have been reported by other studies (e.g., Edmondson et al., 2019; Bengtsson and Haller, 2025), which highlight the lack of quantitative data sources needed to enable realistic assessments of the contribution of self-produced food in cities from all production sources.

Local self-sufficiency has been promoted in Ljubljana for many years (Vadnal and Alič, 2008; SRP MOL 2021–2027, 2020). According to data from the Municipality of Ljubljana, community gardens cover just under 5 hectares, representing less than 2% of all agricultural land in the municipality. The greater unknowns are household gardens, whose number and area are not officially recorded, but rough estimates suggest that their total area exceeds that of Ljubljana's community gardens. This indicates an important but insufficiently explored potential for assessing locally grown food in the urban area.

Due to these data limitations, the currently presented adjusted food balance model for vegetables in the Municipality of Ljubljana likely underestimates the actual volume of local production. This is especially true for the share of household and community gardens, which are not included in the model. In the future, it would therefore be sensible to develop supplementary data collection methods, such as participatory research, spatial analyses, or targeted household surveys. For a more accurate assessment of local food supply in the urban environment, a comprehensive research project should be undertaken, including an inventory of agricultural land, household and community gardens, external trade data, and a detailed analysis of vegetable consumption at the municipal level. Such information would allow for upgrading existing analytical models of production and consumption balances, thereby providing a more complete picture of local self-sufficiency.

Nevertheless, we assess that the presented model, based on national averages and adjustments according to municipal data on land areas and population, reflects the situation in the Municipality of Ljubljana with a sufficiently high degree of reliability. We believe that the differences between estimates calculated using the current methodology and those based on more detailed data would be relatively small and would not significantly affect the main findings of the study.

CONCLUSIONS

In the context of increasing urbanization and the associated challenges to food security, urban agriculture is becoming an important component of urban development, as it can significantly contribute to improving food self-sufficiency and strengthening the resilience of urban communities, particularly during crises and disruptions in supply chains. The study of vegetable production and self-sufficiency in the Municipality of Ljubljana presented in this paper sheds light on the current situation and highlights methodological and data-related gaps that need to be addressed in order to comprehensively assess the potential of urban agriculture.

The results show that Ljubljana, with a self-sufficiency rate of around 22% for fresh vegetables, lags behind the national average, confirming that the city meets most of its vegetable needs through imports or supplies from other regions. The analysis points out that important data sources remain underexplored, particularly those related to household and community gardens, which are not captured in the applied model, despite their contribution to local food self-sufficiency.

One of the key findings is that existing models, based on national averages and official data, offer a valuable starting point, but are unable to reflect all dimensions of urban food production. This is particularly true for non-market forms of production, such as household gardens, whose scale and contribution remain largely unknown. Based on this, we conclude that the actual level of local self-sufficiency in fresh vegetables is likely somewhat higher than the results presented suggest.

To effectively plan and monitor measures related to urban food systems, it would therefore be advisable to develop enhanced data collection methods, such as spatial analyses, participatory research, or targeted household surveys. Such an approach would provide a better understanding of the role of non-market food production in urban settings and strengthen the evidence base for decision-making in spatial planning, sustainable development, and food security.

REFERENCES

Algert, S.J., Baameur, A. and Renvall, M.J. (2014). Vegetable Output and Cost Savings of Community Gardens in San Jose, California. Journal of the Academy of Nutrition and Dietetics 114: 1072–1076.

Bengtsson, A. and Haller, H. (2025). Urban agriculture An assessment of the potential of private gardens to cover the nutritional needs in four Swedish cities. Urban Agriculture & Regional Food Systems 10(1): 1-12.

Bilance proizvodnje in potrošnje kmetijskih proizvodov. (2023). Metodološko pojasnilo za bilance proizvodnje in potrošnje kmetijskih proizvodov. Statistični urad Republike Slovenije. Ljubljana.

CoDyre, M., Fraser, E. and Landman, K. (2014). How Does Your Garden Grow? An Empirical Evaluation of the Costs and Potential of Urban Gardening. Urban Forestry & Urban Greening 14(1): 72-79

De Bon, H., Parrot, L. and Moustier, P. (2010). Sustainable urban agriculture in developing countries. A review. Agronomy for Sustainable Development 30:21–32.

Edmondson, J.L., Blevins, R.S., Cunningham, H., Dobson, M.C., Leake, J.R. and Grafius, D.R. (2019). Grow your own food security? Integrating science and citizen science to estimate the contribution of own growing to UK food production. Plants People Planet (1): 93–97.

EFUA H2020. (2025). European Forum on Urban Agriculture (EFUA). European Union Horizon 2020 Project, available at: https://www.efua.eu/

Ghosh, S. (2021). Urban agriculture potential of home gardens in residential land uses: A case study of regional City of Dubbo, Australia. Land Use Policy 109.

Gittleman, M., Jordan, K. and Brelsford, E. (2012). Using Citizen Science to Quantify Community Garden Crop Yields. Cities and the Environment 5(1): 1-14.

Green report 2023. (2024). Zeleno poročilo za leto 2023. 2024. Travnikar, T. (ed.), Bedrač, M., Bele, S., Bleiweis, A., Brečko, J., Kožar, M., Moljk, B., Telič, V., Zagorc, B. Poročilo o stanju kmetijstva, živilstva, gozdarstva in ribištva v letu 2023. Ljubljana, Kmetijski Inštitut Slovenije.

Hume, I.V., Summers, D.M. and Cavagnaro, T.R. (2021). Self-sufficiency through urban agriculture: Nice idea or plausible reality? Sustainable Cities and Society 68.

Manual to compile supply balance sheets, Vegetables. (1998). Working Party “CROP PRODUCTS STATISTICS” of the Agricultural Statistics Committee EEA. Doc. E/V/006 FR rev. 1

Orsini, F., Kahane, R., Womdim, R. N. and Gianquinto, G. (2013). Urban agriculture in the developing world: A review. Agronomy for Sustainable Development 33:695-720.

Rebernik, D. (1999). Prebivalstveni razvoj Ljubljane po letu 1945. Geografski vestnik 71:41-60.

Rebernik, D. (2004). Razvoj prebivalstva v ljubljanski urbani regiji. Dela - Oddelek za geografijo Filozofske fakultete v Ljubljani 22:89-99.

Saha, M. and Eckelman, M.J. (2017). Growing fresh fruits and vegetables in an urban landscape: A geospatial assessment of ground level and rooftop urban agriculture potential in Boston, USA. Landscape and Urban Planning 165:130-141.

SURS. (2025). Statistical Office of the Republic of Slovenia. Population statistics, available at: https://www.stat.si

SRP MOL 2021–2027. (2020). Strategija razvoja podeželja in urbanega kmetijstva Mestne občine Ljubljana za obdobje 2021–2027. Mestna občina Ljubljana. Available at: https://www.ljubljana.si/assets/datoteke/230.SRPUK-MOL-2021-2027-za-JR-24-06-2021.pdf

Teoh, H., Gwo, W. and Purabi, M. (2024). A review on urban farming: Potential, challenges and opportunities. Innovations in Agriculture 7:1-11.

Vadnal, K. and Alič, V. (2008). Mestno kmetijstvo – oblike in izkušnje. Acta agriculturae Slovenica 91: 191-212

Vadnal, K., Jakše, M., Alič, V. and Jereb-Bolka D. (2010). Is there a future for Krakovo gardens in Ljubljana?. Field Actions Science Reports, Special Issue - Urban Agriculture 1: 1-7.

World population. (2008). World population prospects: the 2008 revision population database. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2020/Jan/un_2008_world_population_prospects-2008_revision_volume-ii.pdf

Suitability of Administrative Standard Output (SO) Database for the Preparation of FADN/ FSDN Selection Plans – Case of Slovenia

Barbara Zagorc, Jure Brečko and Maja Kožar

Agricultural Institute of Slovenia, Agricultural Economics Department, Hacquetova ulica 17, Ljubljana, Slovenia, (maja.kozar@kis.si)

ABSTRACT

This paper presents selected outcomes of the analysis which was conducted as a part of the national project supporting the transition of FADN (Farm Accountancy Data Network) to FSDN (Farm Sustainability Data Network) in Slovenia and strengthening the core FADN. Up until the accounting year 2024, the FADN selection plans were based on the official statistical data on the structure of agricultural holdings, whereas from 2025 onwards they are based on the administrative standard output (SO) database (Record of Standard Output of Agricultural Holdings), managed by the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia. This is also due to the project outcomes which show that using the yearly updated administrative database for the preparation of the FADN/FSDN selection plans could significantly improve the sample representativeness and credibility of the FSDN data in the long term. In the case of using the SO RKG database for the preparation of FADN/ FSDN sampling plans, it was recommended to exclude beforehand those agricultural holdings, which do not meet the criteria of European comparable farms within the framework of statistical farm structure surveys, and to systematically strengthen and regularly assess the implementation of the FADN/FSDN selection plans.

INTRODUCTION

In 2025, FADN (Farm Accountancy Data Network) converted to FSDN (Farm Sustainability Data Network). While the FADN system was primarily focused on collecting micro-economic farm data, the FSDN extends to new farm sustainability topics (Implementing Regulation No. 2024/2746; 2024), mainly environmental and social, which will allow for a more comprehensive assessment of the sustainability of agriculture at the level of agricultural holdings.

With the conversion to FSDN, the FADN/FSDN database, based on harmonised methodology for all European Union (EU) countries, further gains on its status as the most important farm-level database for the assessment of farm-level sustainability, and for supporting evidence-based policy creation and evaluation (Strategic Dialogue on the future of EU agriculture, 2024; A Vision for Agriculture and Food, 2025).

In this paper, we present the selected outcomes of the national project aimed at strengthening the basic FADN and supporting the transition to FSDN system in order to support evidence-based agricultural policy in Slovenia (Kožar et al., 2024a and 2024b). Specifically, we present the outcomes of the analysis of the suitability of the administrative standard output (SO) database for the preparation of FADN/

FSDN selection plans in Slovenia (Kožar et al., 2023). Up until the accounting year 2024, the FADN selection plans were based on the official statistical data on the structure of agricultural holdings (farm structure surveys), while afterwards they are based on the administrative SO database (Record of Standard Output of Agricultural Holdings – SO RKG), managed by the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia (MAFF). This is also due to the project outcomes showing that using the yearly updated administrative database for the preparation of the FADN/FSDN selection plans could significantly improve the sample representativeness and credibility of the FSDN data in a longer term.

MATERIAL AND METHODS

We analyzed FADN selection plans for the accounting years 2023 and 2024 and compared them with the data from the Record of Standard Output of Agricultural Holdings (hereafter SO RKG) for the year 2022, as well as for the years 2019, 2020 and 2023. Several comparisons were performed: population of agricultural holdings above the economic threshold of 4,000 EUR SO (i.e. economic size class ≥III) compiled from the annually updated SO RKG database (for the year n-1) compared with the FADN population based on the statistical data on structure of agricultural holdings, for different years. Analysis was performed at the level of principal types of farming and economic size classes as defined in the Commission Implementing Regulation (EU) 2024/2746 (2024), which states in Annex IV that for classifying agricultural holdings "according to the Union farm typology (in which the type of farming is defined by main production activities) and for determining economic farm size, the Standard output (SO) is used".

Standard output (SO) is a relatively simple economic indicator – the expected average ("standard") value of gross production of an agricultural holding, based on its production structure (Delegated Regulation No. 2024/1417, 2024). As mentioned, it enables classification of agricultural holdings into types of farming and economic size classes, thus enabling in-depth economic analyses at different levels of agriculture. The "total SO of a holding is the sum of the individual production units of a specific holding multiplied by their respective SOC" (Annex IV of the Implementing Regulation (EU) 2024/2746, 2024). "Standard output coefficient (SOC) is the average monetary value of gross production of each agricultural variable ..., corresponding to the average situation in a given region, per unit of production... SOCs are updated at least every time a European survey on the structure of agricultural holdings is conducted." (Annex IV of the Implementing Regulation (EU) 2024/2746, 2024). While the SOCs for the purpose of the statistical farm-structure survey are updated only when European surveys on farm structure are conducted (five-year average; Delegated Regulation No. 2024/1417, 2024), the SOCs (five-year averages) within the SO RKG database are annually updated. Principal types of farming and economic size classes, referenced in this paper are listed in Table 2 and 3 in Annex.

The calculation of the total SO at the level of individual agricultural holdings and integration of these data into the administrative data system of MAFF has significantly increased the usefulness and analytical value of these data in case of Slovenia (Zagorc et. al., 2022a, 2023 and 2024). Primarily, these data are used for monitoring the state of Slovenian agriculture and enable evidence-based agricultural policy creation and implementation at different levels (e.g., calculation of economic threshold for participation in specific policy measures of the current strategic CAP plan for 2023–2027).

RESULTS

As presented in Table 1, the year-on-year changes in the number of agricultural holdings included in the calculation of the SO at the aggregate level are usually less than one percent, while the number of agricultural holdings included in FADN selection plans vary between years. The number of agricultural holdings in the selection plan for 2024 was at the level of the selection plan for 2023. Furthermore, there was also almost no change between 2021/2020, while larger differences occurred between datasets for 2022 and 2021 (–4%) and 2023 and 2022 (+6%) (more results in Kožar et al., 2024a). Larger year-on-year changes in the total number of agricultural holdings and by type of farming in the FADN selection plans occur in those years when the newer data on the typology and economic size of holdings from the farm structure surveys, which are not conducted annually by the Statistical Office of Slovenia, were taken into account.

At the time of preparation of the FADN selection plan for accounting year 2024 (October 2023), in the administrative SO database (Record of Standard Output of Agricultural Holdings) data for the year 2022 were available. In this administrative SO database for 2022, at the aggregate level (economic size class ≥III) the number of agricultural holdings exceeded the number of agricultural holdings in the FADN selection plan for 2024 by 2%. The largest differences were, similar for all analyzed years, calculated for the specialist horticulture holdings (types of farming: 21+22+23). The SOC coefficients for these types are calculated in more detail at lower levels of principal types of farming in case of the administrative SO RKG database compared to the official EU survey statistical methodology. For specialist field crops holdings (types of farming: 15+16), a larger difference in the number of agricultural holdings can be observed due to beforehand mentioned more detailed SOCs and also due to the high prices of agricultural products in 2022 (SOC coefficients "2020" used: average for the period 2018–2022), which were not yet available in the selection plan for 2024 (SOC coefficient "2017" used: average for the period 2015–2019). There are significantly less agricultural holdings among specialist permanent crops holdings (types of farming: 36+37+38) in the SO RKG database, which is a result of more exceptionally poor harvests in the intensive orchards in the period 2018–2022 (reflected in the SO RKG database for year 2022 – SO RKG 2022) than in the period 2015–2019 (reflected in the FADN selection plan for the accounting year 2024).

One of the major advantages of the administrative SO RKG database compared to the farm structure survey data is the annual updating of SOC coefficients, which are a multiplier of the farm-level production data (area, hectare yields, animals, live weight gains, bee colonies) from MAFF's administrative registers and databases and prices of agricultural products. This results in relatively smaller interannual fluctuations in the number of agricultural holdings in population and in the structure of population by production types and economic size classes. This is also evident from the Fig. 1 showing relative stability of the number of agricultural holdings by principal production types among different years. Further in years, when the agriculture structural surveys are conducted or in typical years (production-wise), the outcomes are very similar (Kožar et al., 2024a). Changes of bigger magnitude can be a consequence of extreme price/production fluctuations, e.g., price surge in types 15 and 16 (both specialist field crops) in year 2023 compared to 2020 or structural changes in types 45 (specialist dairy) and 46 (specialist cattle – rearing and fattening) in year 2023 compared to 2020.

Table 1. Comparison of populations of agricultural holdings above FADN economic threshold (from 4,000 EUR SO or economic size class ≥III) in the administrative SO RKG database for years 2022 and 2023, and in the FADN selection plans for accounting years 2023 and 2024.

Index SO RKG 2023a/ SO RKG 2022a (population SO RKG 2022 = 100)

Principal type of farming[b]	Economic size class[b]					Total ≥III
	III	IV+V	VI+VII	VIII+IX	>IX	
15+16	113	122	148	127	122	**119**
21+22+23	101	87	95	122	183	**96**
35	94	96	101	103	92	**97**
36+37+38	101	103	108	130	100	**104**
45	31	55	78	112	125	**81**
46	95	108	114	126	50	**104**
47	66	87	163	155		**117**
48	104	104	114	120		**104**
51+52+53	57	60	69	98	106	**81**
61	98	111	97	80	133	**101**
73+74	83	93	89	98	200	**88**
83+84	96	104	114	111	78	**102**
Total	**99**	**104**	**99**	**111**	**112**	**101**

Index FADN selection plan 2024a / FADN selection plan 2023a (population FADN selection plan 2023 = 100)

Principal type of farming[b]	Economic size classb					Total ≥III
	III	IV+V	VI+VII	VIII+IX	>IX	
15+16	99	100	100	99	100	**99**
21+22+23	98	97	103	104	133	**101**
35	98	99	99	100	100	**99**
36+37+38	99	99	100	98	100	**99**
45	102	100	100	100	100	**100**
46	100	100	100	100	100	**100**
47	100	100	100	100		**100**
48	99	99	100	100		**99**
51+52+53	100	100	100	99	100	**100**
61	99	99	100	100	100	**99**
73+74	100	100	99	100	100	**100**
83+84	100	100	100	100	100	**100**
Total	**99**	**100**	**100**	**100**	**101**	**100**

Index SO RKG 2022a / FADN selection plan 2024a (population FADN selection plan 2024 = 100)

Principal type of farming[b]	Economic size class[b]					Total ≥III
	III	IV+V	VI+VII	VIII+IX	>IX	
15+16	129	123	82	67	82	**120**
21+22+23	298	223	198	153	150	**211**
35	94	84	75	108	120	**86**
36+37+38	67	72	94	131	140	**74**
45	74	83	92	118	150	**94**
46	101	114	113	120	100	**108**
47	110	111	83	126		**100**
48	145	146	103	100		**142**
51+52+53	102	118	141	141	157	**133**
61	101	98	103	138	150	**101**
73+74	111	126	125	116	200	**119**
83+84	90	86	96	94	180	89
Total	**103**	**102**	**97**	**115**	**138**	**102**

Index SO RKG 2023a / FADN selection plan 2024a (population FADN selection plan 2024 = 100)

Principal type of farming[b]	Economic size class[b]					Total ≥III
	III	IV+V	VI+VII	VIII+IX	>IX	
15+16	147	149	122	85	100	**143**
21+22+23	300	193	187	187	275	**201**
35	89	80	76	111	110	**84**
36+37+38	67	74	101	171	140	**77**
45	23	46	72	132	188	**76**
46	96	123	128	152	50	**112**
47	72	96	135	196		**117**
48	150	151	116	120		**148**
51+52+53	58	71	98	138	165	**108**
61	99	110	100	110	200	**103**
73+74	92	117	111	114	400	**105**
83+84	86	89	109	105	140	**90**
Total	**102**	**106**	**96**	**127**	**155**	**103**

[a] Note: SO RKG 2022: population MAFF for year 2022, SOC coefficients "2019" (average for the period 2017–2021); SO RKG 2023: population MAFF for year 2023, SOC coefficients "2020" (average for the period 2018–2022); FADN selection plan for accounting year 2023: population for year 2022 (by Statistical Office of Republic of Slovenia), SOC coefficients "2017" (average for the period 2015–2019); FADN selection plan for accounting year 2024: population for year 2023 (by Statistical Office of Republic of Slovenia), SOC coefficients "2017" (average for the period 2015–2019).

[b] Principal types of farming and economic size classes, referenced in Table 1, are listed in Annex.

Source: Record of Standard Output of Agricultural Holdings – aggregate data (MAFF); FADN selection plans for the accounting years 2023 and 2024 (MAFF); own calculations

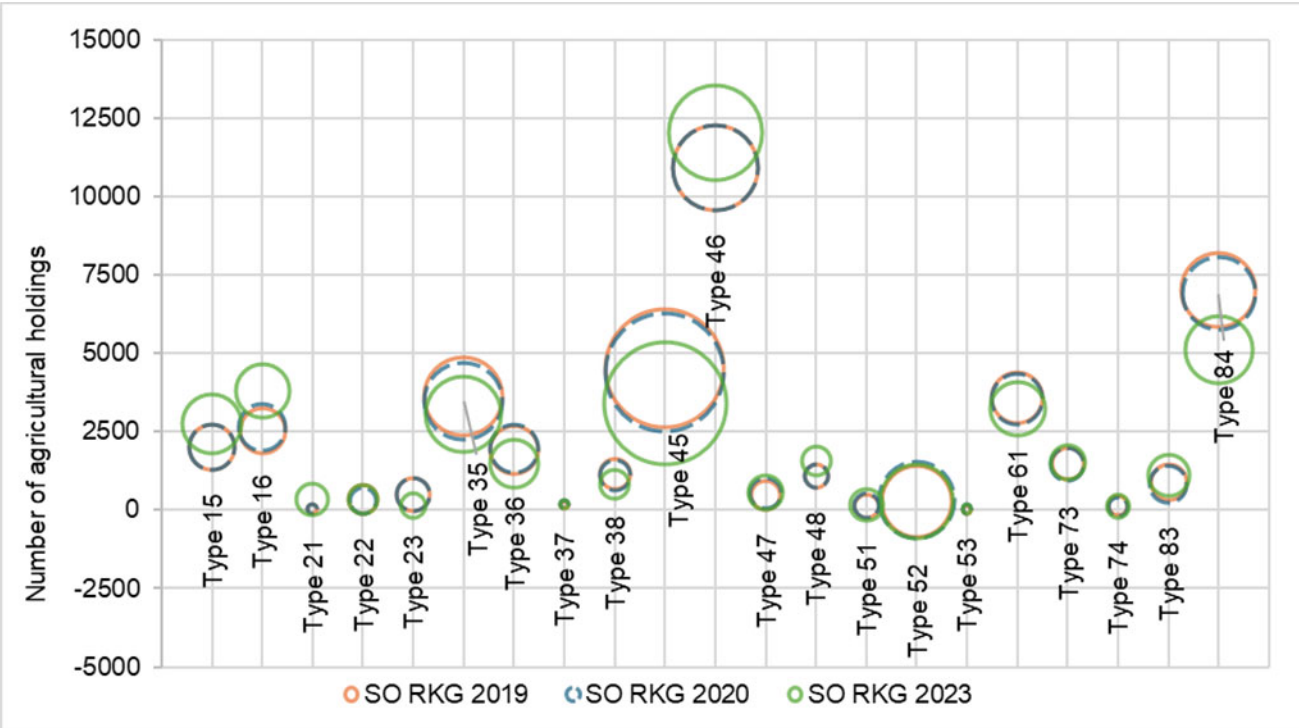

Figure 1. Population of agricultural holdings above FADN threshold (4,000 EUR SO or economic size class ≥III): Comparing administrative SO RKG database for three years (2019, 2020, 2023) by principal type of farminga (bubble size: share of total SO of Slovenian agriculture).

[a] Principal types of farming, referenced in Fig. 1, are listed in Annex (Table 2).

Source: Record of Standard Output of Agricultural Holdings – aggregate data (MAFF; presented also in Zagorc et. al., 2022a, 2023 and 2024); own calculations

DISCUSSION

The key advantage of using the administrative SO register for preparing the FADN/FSDN sampling plan is the annual calculation of the SO of agricultural holdings based on updated SOC coefficients (average of the last five consecutive years) and data on areas and livestock on agricultural holdings from the MAFF's administrative registers and databases. This way, the information on the economic size class and type of farming of the agricultural holding is more precise and up to date, which is crucial in the circumstances of rapid structural changes in the Slovenian agriculture (Kožar et al., 2024a).

One potential disadvantage of using the administrative SO data for the preparation of FADN/FSDN sample plans could be that although the methodology for estimating the SO of agricultural holdings (Pravilnik ..., 2023) does largely take into account the EU legislation, there are certain deviations. This could lead to weaker comparability with the approaches of preparing FSDN sample plans in other EU countries. The outcomes of our analysis show that the number of agricultural holdings included in the SO RKG database at the aggregate level exceed the agricultural holdings population according to the official statistical data and that certain deviations by types of farming and economic size classes remain, however as shown in the results chapter, they are explainable (Zagorc et al., 2022b). In case of using the SO RKG database for the preparation of FADN/FSDN sampling plans, it was recommended to exclude beforehand those agricultural holdings, which do not meet the criteria of European comparable farms within the framework of statistical surveys of the structure of agricultural holdings.

An overall project recommendation (Kožar et al., 2024a) was to systematically strengthen and regularly assess the implementation of the FADN/FSDN selection plans and further, to systematically collect additional metrics and information about the FADN/FSDN population to upgrade the statistical evaluation of the sample representativeness and of the reliability of the selected FADN/FSDN variables.

ACKNOWLEDGEMENT

The paper presents the results of the project V5-2229 "Supporting evidence based agricultural policy in Slovenia: reinforcing core FADN and supporting activities for conversion to FSDN" supported by the Slovenian Research and Innovation Agency and the Ministry of Agriculture, Food and Forestry of the Republic of Slovenia.

REFERENCES

A Vision for Agriculture and Food. (2025). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee of the Regions a Vision for Agriculture and Food Shaping together an attractive farming and agri-food sector for future generations. COM/2025/75 final. Brussels, 19.2.2025. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025DC0075

Delegated Regulation No. 2024/1417. (2024). Commission Delegated Regulation (EU) 2024/1417 of 13 March 2024 supplementing Council Regulation (EC) No 1217/2009 setting up the Farm Sustainability Data Network with rules for annual income determination, holding sustainability analysis and access to data for research purposes, and repealing Commission Delegated Regulation (EU) No 1198/2014. http://data.europa.eu/eli/reg_del/2024/1417/oj

FADN selection plans for accounting years 2023 and 2024. (2024). Ljubljana: Ministry of Agriculture, Forestry and Food of the Republic of Slovenia.

Implementing Regulation No. 2024/2746. (2024). Commission Implementing Regulation (EU) 2024/2746 of 25 October 2024 laying down rules for the application of Council Regulation (EC) No 1217/2009 setting up the Farm Sustainability Data Network and repealing Commission Implementing Regulation (EU) 2015/220. http://data.europa.eu/eli/reg_impl/2024/2746/oj

Kožar, M., Bedrač, M., Bele, S., Bleiweis, A., Brečko, J., Hiti Dvoršak, A., Moljk, B., Telič, V., Travnikar, T., Zagorc, B., Novak, A., Rac, I., Šumrada, T., Tomšič, M., Žgajnar, J., Cör, T., Demšar-Benedičič, A., Šnut, L., Šenk, D. and Beguš, M. (2024a). Podpora na dejstvih utemeljeni kmetijski politiki v Sloveniji: krepitev osnovnega FADN in podpora pri prehodu v FSDN (Supporting evidence based agricultural policy in Slovenia: reinforcing core FADN and supporting activities for conversion to FSDN). Final report. Ljubljana: Kmetijski inštitut Slovenije, Univerza v Ljubljani, Biotehniška fakulteta; Kranj: KGZS – KGZ Kranj.

Kožar, M., Zagorc, B. and Bele, S. (2023). Predlogi prilagoditve uradnega vzorca FADN: Poročilo (Rezultat R6) v okviru projekta CRP V5-2229 (Podpora na dejstvih utemeljeni kmetijski politiki v Sloveniji: krepitev osnovnega FADN in podpora pri prehodu v FSDN). Ljubljana: Kmetijski inštitut Slovenije.

Kožar, M., Zagorc, B., Telič, V., Bele, S., Bedrač, M., Demšar-Benedičič, A. and Rac, I. (2024b). Final outcomes of national project on compiling new sustainability data on FADN farms in Slovenia. Presentation at 29th PACIOLI workshop, October 6–9, 2024, Montegrotto Terme, Italy. https://www.pacioli.org/PacioliImages/documents/1d9a7828-eef5-4d41-88fc-c1dbfea5e1d5.pdf

Pravilnik o izračunu standardnega prihodka kmetijskih gospodarstev. (2023). Uradni list RS, 21/2023. https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina/2023-01-0366/pravilnik-o-izracunu-standardnega-prihodka-kmetijskih-gospodarstev

SO RKG (2022). Evidenca standardnega prihodka kmetijskih gospodarstev za leto 2020. Ljubljana: Ministry of Agriculture, Forestry and Food of the Republic of Slovenia. (Calculations by Agricultural Institute of Slovenia)

Strategic Dialogue on the future of EU agriculture. (2024). A shared prospect for farming and food in Europe. The final report of the Strategic Dialogue on the future of EU agriculture. Strategic Dialogue on the Future of EU Agriculture. Brussels, September 2024. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/main-initiatives-strategic-dialogue-future-eu-agriculture_en

Zagorc, B., Brečko, J., Bele, S., Telič, V., Bedrač, M. and Kožar, M. (2024). Poročilo o oceni standardnega prihodka kmetijskih gospodarstev za leto 2023. Ljubljana: Kmetijski inštitut Slovenije.

Zagorc, B., Brečko, J., Ložar L., Bele S., Kožar M. and Bedrač M. (2022a). Poročilo o oceni standardnega prihodka kmetijskih gospodarstev za leti 2019 in 2020. Ljubljana, Kmetijski inštitut Slovenije.

Zagorc, B., Brečko, J., Ložar L., Bele, S., Hiti Dvoršak, A., Bedrač, M. and Kožar, M. (2023). Poročilo o oceni standardnega prihodka kmetijskih gospodarstev za leto 2022. Ljubljana: Kmetijski inštitut Slovenije.

Zagorc, B., Brečko, J., Ložar, L., Bele, S., Kožar, M., Bedrač, M., Cunder, T., Hiti Dvoršak, A., Moljk, B. and Travnikar, T. (2022b). Metodologija ocene standardnega prihodka kmetijskih gospodarstev. Ljubljana: Kmetijski inštitut Slovenije.

ANNEX: GENERAL AND PRINCIPAL TYPES OF FARMING AND GROUPED ECONOMIC SIZE CLASSES

Table 2. General and principal types of farming (Source: Implementing Regulation No. 2024/2746 (2024): Annex IV)

General type of farming	**Principal type of farming**
1. Specialist field crops	15. Specialist cereals, oilseeds and protein crops
	16. General field cropping
2. Specialist horticulture	21. Specialist horticulture indoor
	22. Specialist horticulture outdoor
	23. Other horticulture
3. Specialist permanent crops	35. Specialist vineyards
3. Specialist permanent crops	36. Specialist fruit and citrus fruit
	37. Specialist olives
	38. Various permanent crops combined
4. Specialist grazing livestock	45. Specialist dairy
4. Specialist grazing livestock	46. Specialist cattle – rearing and fattening
	47. Cattle dairy, rearing and fattening combined
	48. Sheep, goats and other grazing livestock
5. Specialist granivores	51. Specialist pigs
	52. Specialist poultry
	53. Various granivores combined
6. Mixed cropping	61. Mixed cropping
7. Mixed livestock	73. Mixed livestock, mainly grazing livestock
	74. Mixed livestock, mainly granivores
8. Mixed crops - livestock	83. Field crops – grazing livestock combined
	84. Various crops and livestock combined

Table 3. Grouped economic size classes of holdings (Source: Adapted from Implementing Regulation No. 2024/2746 (2024): Annex V)

Grouped economic size classes	**Limits in EUR**
III	from 4 000 to less than 8 000
IV+V	from 8 000 to less than 25 000
VI+VII	from 25 000 to less than 100 000
VIII+IX	from 100 000 to less than 500 000
>IX (classes IX, X, XI, XII, XIII, and XIV)	from 500 000

The Potential Relationship Between Direct Payments Distribution and Agricultural Productivity: An EU Overview

Magdalena Zrakić Sušac, Lari Hadelan, Josip Juračak and Petra Posedel Šimović

University of Zagreb Faculty of Agriculture, Svetošimunska cesta 25, 10000 Zagreb, Croatia, (mzrakic@agr.hr)

ABSTRACT

This study investigates the potential relationship between inequality in agricultural direct aid distribution and productivity in the European Union. Using Eurostat data and the Gini coefficient to measure inequality, this study analyses the possible correlations between direct aid distributions and various productivity indicators. The findings reveal significant negative correlations between inequality and work-unit-based productivity measures, suggesting that a more equitable direct aid distribution could enhance labor productivity. However, its relationship with land-based productivity measures remains unclear. A comparative analysis of Croatia, Austria, and Slovenia demonstrated the concentration of direct aid recipients in lower categories, supporting small- and medium-sized farms. This study emphasizes the importance of equitable direct aid distribution in promoting agricultural productivity and recommends that policymakers consider these dynamics when designing direct aid frameworks to enhance productivity and support sustainable agricultural development.

INTRODUCTION

Agricultural subsidy plays a crucial role in shaping productivity and income boosting in the farming sector (Biagini et al., 2023; Garrone et al., 2019; Mamun, 2024). However, the relationship between subsidy inequality and agricultural productivity is complex and multifaceted, with studies showing mixed results in different contexts. This study aims to explore the potential relationship between the distribution of direct aid among beneficiaries (represented by the Gini coefficient) and various development indicators in the EU agricultural sector.

Previous studies have found varying effects of subsidies on farm productivity and efficiency. For instance, input subsidies have shown strong positive impacts on output growth and labor productivity, whereas output payments have smaller positive effects on output growth only (Mamun, 2024). However, some studies have revealed contradictory results; for example, subsidies negatively affect farm productivity but positively influence technical efficiency in Norwegian grain farms (Kumbhakar & Lien, 2010).

Subsidy distribution can lead to significant inequalities, potentially harming the overall productivity of the agricultural sector. In some regions, direct aid programs tend to benefit elites, which can negatively impact poor farmers and hinder sector-wide growth (Goyal and Nash, 2017). Unequal land distribution, often reflected in the high Gini coefficients for landholdings, is associated with lower productivity. Research has shown that reducing land inequality can lead to substantial increases in productivity (Vollrath, 2007).

In the European Union, the distribution of agricultural payments is uneven, with 20% of CAP beneficiaries receiving 80% of payments (European Commission, n.d.a). The distribution of subsidies varies significantly across regions, influenced by factors such as predominant farming systems and historical land ownership patterns.

Support through CAP strategic plans is primarily administered as area-based payments. Agricultural subsidies serve as a critical policy instrument to influence the distribution of farm income and enhance productivity. These subsidies can exert diverse effects on economic inequality, often quantified by the Gini coefficient, and consequently impact broader development indices. Notably, agricultural subsidies, particularly direct payments, tend to be concentrated among a limited number of large farms, potentially exacerbating income inequality (Sinabell et al., 2013). For instance, in 2010, less than 2% of direct payment recipients accounted for a substantial share of total subsidies, underscoring a skewed distribution that may elevate the Gini coefficient (Severini and Tantari, 2015). The distribution of subsidies and their impact on inequality exhibit significant regional variation. For example, in Portugal, the allocation of direct payments is shaped by prevailing farming systems, with larger farms and specific crop types receiving greater support, which can intensify regional income disparities (Dinis, 2024).

In Central and Eastern European countries, an uneven distribution of subsidies has been observed, with large farms frequently dominating fund allocation, resulting in higher Gini coefficients in these regions than the EU average (Sadłowski et al., 2022). Subsidies are pivotal for sustaining farm profitability, which is vital for rural economic development. However, the unequal distribution of these subsidies may constrain their efficacy in fostering equitable economic growth (Severini and Tantari, 2015). The concentration of subsidies on larger farms may impede the development of smaller farms, which is essential for sustainable rural development and mitigating regional disparities (Sinabell et al., 2013).

The issue of payment distribution within the CAP is highly complex, involving a number of interrelated factors, from production structure to the institutional and economic development of Member States.

Actual policy reforms aimed at more equitable redistribution of subsidies, such as the introduction of redistributive payments and capping mechanisms, have been proposed to reduce inequality and enhance development outcomes. These measures can potentially decrease the Gini coefficient by providing increased support to smaller farms. The success of these reforms is contingent on their implementation at the national level, as member states possess considerable discretion in shaping subsidy policies (Severini & Tantari, 2015).

Despite the importance of this topic, there is a lack of comprehensive analysis of how direct aid inequality, specifically measured through the Gini coefficient, impacts agricultural productivity across different European contexts. This study aimed to fill part of this gap by addressing the following research questions:

1. Is there a relationship between the (uneven) distribution of beneficiaries of paid direct payments at the member state level, and national output per agricultural work unit or per hectare in the EU?
2. If yes, what is the relationship between direct aid distribution inequality and gross value added per agricultural work unit per hectare?
3. What are the results of the comparative analysis of direct aid distributions in Croatia, Slovenia, and Austria?

MATERIAL AND METHODS

Data Sources

This study utilized secondary data from Eurostat database to ensure the reliability and comparability of indicators across different EU member states. The following development indicators from Eurostat were used to measure productivity: Agricultural Output per Agricultural Work Unit, Agricultural Output per Utilized land area, Gross Value-Added per Agricultural Work Unit, and Goss value-added per Utilized land area. These indicators were chosen because they provide a comprehensive view of agricultural productivity, capturing both labor and land efficiency. Additionally, data (European Commission, 2024) on the distribution of direct aid to farmers through the European Agricultural Guarantee Fund (EAGF) for the 2022 financial year were used to analyse the impact of direct aid distribution on productivity.

Calculation of Gini Coefficient

The Gini coefficient, a measure of inequality, was calculated using data from the stratification of agricultural support classes and the distribution of direct aid recipients (European Commission, 2024: European Commission, Directorate-General for Agriculture and Rural Development, Indicative Figures on the distribution of aid, by size class of aid, received in the Context of Direct Aid Paid to the Producers According to Regulation (EU) No 1307/2013 (Financial Year 2022)). The Gini coefficient was calculated by plotting the cumulative share of the population against the cumulative share of income or subsidies received, resulting in a Lorenz curve. The Gini coefficient in the study shows the evenness of the distribution of the number of users of all direct payments into the following classes: less than 0 €, between 0 and 0.5 K €, between 0.5 K and 1.25 K €, between 1.25 K and 2 K €, between 2 K and 5 K €, between 5 K and 10 K €, between 10 K and 20 K €, between 20 K and 50 K €, between 50 K and 100 K €, between 100 K and 150 K €, between 150 K and 200 K €, between 200 K and 250 K €, between 250 K and 300 K €, between 300 K and 500 K €, and more than 500 K € in each EU member state.

$$G = \frac{2\sum_{i=1}^{n} i y_i}{n\sum_{i=1}^{n} y_i} - \frac{n+1}{n}.$$

Correlation Analysis

Spearman's rank correlation coefficient was used to examine the relationship between the direct aid distribution (Gini) and productivity measures. This non-parametric measure assesses the strength and direction of the association between the two ranked variables, providing insights into the correlation between direct allocation and productivity outcomes. Spearman's correlation coefficient has been selected because it measures monotonic relationships, uses data ranks, is robust to outliers, applicable to ordinal and non-normally distributed data, and is easy to interpret.

$$r_s = 1 - \frac{6\sum D^2}{N^3 - N}$$

RESULTS AND DISCUSSION

Table 1 provides a comprehensive overview of Gini Coefficient and various agricultural productivity metrics across different European countries.

Gini Coefficient and Output and Gross Value Added

The measure of inequality (GINI) in the direct aid distribution classes varies widely among countries. For example, Malta (MT) has the highest Gini coefficient at 86, indicating a highly unequal distribution of subsidies, whereas the Czech Republic (CZ) has the lowest at 48, suggesting a more equitable distribution. The average Gini coefficient across all the countries was approximately 67.04.

Countries with higher Gini coefficients, such as Malta (MT) and Romania (RO), tend to have lower productivity performance when considering output per agricultural work unit (OUTPUT/AWU) and gross value-added per used land area (GVA/HA). For instance, despite its high Gini coefficient, Malta shows a relatively high OUTPUT/UTILISED AREA (EUR/HA) at 13,828, but its GVA/HA is significantly lower at 5,211. This suggests that, while output per area is high, the value added per hectare is not proportionally high, indicating inefficiencies in value addition.

Table 1. Agriculture Development Indicators and Gini coefficient for EU members in 2022 and Spearman's Rho (**ρ**) Correlation analysis results

Geo	Gini[a]	Output of the agricultural 'industry' (milion EUR)	Gross value added at basic prices	Annual work units (000)	Utilised agricultural area (ha)	Output/ Awu (Eur/ Awu)[a]	Output/ Utilised Area (Eur/ Ha)[a]	Gva/Awu[a]	Gva/Ha[a]
BE	65	11,694.11	2,837.51	51.57	1,368,120	226762	8548	55022	2074
BG	58	6,596.76	3,023.42	152.7	4,564,150	43201	1445	19800	662
CZ	48	7,809.85	2,608.17	93.93	3,492,570	83145	2236	27767	747
DK	57	14,039.96	3,425.10	47.43	2,629,930	296014	5339	72214	1302
DE	59	77,923.88	31,812.25	463.83	16,595,020	168001	4696	68586	1917
EE	56	1,630.46	488.45	17.19	975,320	94849	1672	28415	501
IE	71	12,922.13	5,041.87	156.94	4,920,270	82338	2626	32126	1025
GR	70	14,600.71	6,712.02	328.76	3,916,640	44411	3728	20416	1714
ES	62	63,068.36	29,380.95	850.29	23,913,680	74173	2637	34554	1229
FR	66	97,344.81	40,160.32	722.41	27,364,630	134750	3557	55592	1468
HR	73	3,245.19	1,717.11	173.31	1,505,430	18725	2156	9908	1141
IT	68	72,678.76	37,540.26	978.6	12,523,540	74268	5803	38361	2998
CY	80	822.35	340.18	18.64	134,140	44117	6131	18250	2536
LV	69	2,354.77	825.86	62.61	1,968,960	37610	1196	13191	419
LT	68	5,321.49	2,031.07	120.1	2,914,550	44309	1826	16911	697
LU	69	597.24	172.72	3.53	132,140	169190	4520	48929	1307
HU	64	10,398.36	3,450.69	289.53	4,921,740	35915	2113	11918	701
MT	86	135.51	51.07	6.12	9,800	22142	13828	8345	5211
NL	69	40,556.20	13,302.60	161.55	1,817,900	251044	22309	82344	7318
AT	70	10,540.17	4,483.69	120.39	2,602,670	87550	4050	37243	1723
PL	72	39,546.32	14,253.27	1,427.50	14,784,120	27703	2675	9985	964
PT	73	10,669.55	3,385.66	223.1	3,963,940	47824	2692	15176	854
RO	80	22,218.82	9,929.62	1,035.00	12,762,830	21467	1741	9594	778

SI	73	1,590.98	523.19	72.92	483,440	21818	3291	7175	1082
SK	57	3,001.11	888.74	38.6	1,862,650	77749	1611	23024	477
FI	65	5,824.62	1,719.83	63.9	2,281,710	91152	2553	26914	754
SE	62	8,251.22	2,773.58	56.21	3,005,810	146793	2745	49343	923
Spearman's Rho[a]						rs = -0.56623, p (2-tailed) = 0.00208.	rs = 0.26797, p (2-tailed) = 0.17657.	rs = -0.54971, p (2-tailed) = 0.00298.	rs = 0.368, p (2-tailed) = 0.05894.

[a] Own calculation

Source: Eurostat 2025. Economic accounts for agriculture - values at current prices; European Commission. (2024). Direct aid breakdown. Distribution of direct aid to farmers – indicative figures 2022 financial year. European Union.

Productivity Indicators and Spearman's Rank Correlation Coefficient

The study utilized secondary data from Eurostat databases to measure agricultural productivity using several key indicators. The output per Agricultural Work Unit (AWU) represents the output per worker, with countries such as the Netherlands (NL) and Denmark (DK) showing the highest values, indicating the leading productivity per work unit among EU countries. The output per Utilized Area measures the output per hectare of utilized agricultural land, where the Netherlands again demonstrated high productivity, reflecting efficient land use. The Gross Value Added (GVA) per Agricultural Work Unit indicates the value added per worker, with higher values in countries such as the Netherlands and Denmark suggesting greater efficiency and value addition per worker. Finally, GVA per hectare shows the value added per hectare, with countries such as the Netherlands and Italy (IT) exhibiting more efficient and valuable land use.

Spearman's rank correlation coefficients (rs) provide insight into the relationships between the Gini coefficient and various productivity measures. The correlation between the Gini coefficient and output per AWU is significantly negative (rs = -0.56623, p = 0.00208), indicating that higher inequality in direct aid distribution is associated with lower output per worker and that a more equitable direct aid distribution can enhance worker productivity. Conversely, the correlation between the Gini coefficient and output per hectare is positive but not statistically significant (rs = 0.26797, p = 0.17657), implying that inequality does not have a clear impact on output per hectare, and other factors such as land management practices may play a more significant role. The correlation between the Gini coefficient and GVA per AWU is significantly negative (rs = -0.54971, p = 0.00298), reinforcing the idea that higher inequality is associated with lower value-added per worker, supporting the need for equitable direct aid distribution. Finally, the correlation between the Gini coefficient and GVA per hectare is positive but marginally significant (rs = 0.368, p = 0.05894), suggesting a potential positive relationship between inequality and value-added per hectare, although this result is less robust and may imply that higher inequality might be associated with more efficient land use in some cases.

Croatia, Slovenia and Austria - Comparative Analysis of Direct aid Distribution

Agriculture plays a pivotal role in the economic and rural development of Croatia, Slovenia, and Austria, each exhibiting unique characteristics that are influenced by historical, geographical, and policy factors. According to the national strategic plans of the Common Agricultural Policy (CAP), the following is a brief description of the agricultural structure of each member state.

Croatian agriculture is characterized by small family agricultural holdings and very diverse because, in a small area, there are simultaneously three agro-climatic zones - Central European, mountainous, and Mediterranean. This sector contributes with approximately 3% to the economy, with a focus on arable land (68%) and permanent grasslands and meadows (26%). The main agricultural products include cereals, industrial crops, forage plants, vegetables, and wines. The government aims to support sustainable development, improve living conditions in rural areas, and protect natural resources through incentives and policies.

Similarly, Slovenia's agriculture is predominantly composed of small family farms, with 60% of the holdings having less than five hectares of land. The agricultural sector is vital for rural development, utilizing 36% of the land for agriculture and 61% covered by forests. Key agricultural products include forage plants, milk, wines, and cattle. Despite the natural constraints impacting agricultural production, Slovenia's CAP Strategic Plan focuses on ensuring food security and sustainable development.

Austria's agricultural sector is characterized by a mix of small- and medium-sized family farms, with crops accounting for approximately 50% of the agricultural output and animal production slightly over 40%, with milk production being a major contributor. Rural areas in Austria cover approximately 75% of the country's land area and are home to over 3.6 million people. Austria's CAP Strategic Plan for 2023-2027 aims to enhance sustainable competitiveness, resilience, and environmental protection in agriculture.

Table 1 provides a detailed breakdown of the number of direct aid recipients across different stratification categories for the three EU member states: Croatia (HR), Slovenia (SI), and Austria (AT).

Table 2. Distribution of direct aids to the producers - Financial year 2022, Number of beneficiaries per range of expenditure in Croatia, Slovenia and Austria

Size-class of aid (all direct payments)	Croatia	Austria	Slovenia
< 0 €	221	4	n/a
≥ 0 and < 0.5 K €	24298	1885	10929
≥ 0.5 K and < 1.25 K €	38640	15788	17892
≥ 1.25 K and < 2 K €	15779	10673	9029
≥ 2 K and < 5 K €	16911	29888	11475
≥ 5 K and < 10 K €	6416	24271	3600
≥ 10 K and < 20 K €	4184	15736	1374
≥ 20 K and < 50 K €	2094	4289	411
≥ 50 K and < 100 K €	332	381	35
≥ 100 K and < 150 K €	67	51	6
≥ 150 K and < 200 K €	37	21	2
≥ 200 K and < 250 K €	10	3	1
≥ 250 K and < 300 K €	9	4	1
≥ 300 K and < 500 K €	19	4	4
≥ 500 K €	24	3	3
Total	**109041**	**103001**	**54762**

Source: European Commission. (2024). Direct aid breakdown. Distribution of direct aid to farmers – indicative figures 2022 financial year.

Some key observations and differences in the distribution of agricultural subsidies among these countries are as follows:

- In Croatia (HR), the total number of direct aid recipients was 109,041. The average CAP income support per beneficiary in 2022 was €4,230, with an average of €410 per hectare (European Commission, n.d.b). Most recipients fell within the lower direct aid categories, particularly in the ranges of "≥ 0 and < 0.5 K €" (24,298 recipients, 22,2% of all recipients) and "≥ 0.5 K and < 1.25 K €" (38,640 recipients, 35,4%). There are very few recipients in the higher direct aid categories, with only 24 recipients (2,2%) receiving subsidies of "≥ 500 K €".
- In Austria (AT), the total number of direct aid recipients was 103,001. The average CAP income support per beneficiary in 2022 was €7,950, with an average of €357 per hectare (European Commission, n.d.b). Like Croatia, Austria has a significant number of recipients in the lower direct aid categories, but a notable concentration in the "≥ 2 K and < 5 K €" category (29,888 recipients, 29,02%). Austria also has a small number of recipients in the higher direct aid categories, with only three recipients receiving subsidies of "≥ 500 K €".
- In Slovenia (SI), the total number of direct aid recipients is 54,762. The average CAP income support per beneficiary in 2022 was €3,010, with an average of €374 per hectare (European Commission, n.d.b). Slovenia shows a similar pattern, with many recipients in the lower direct aid categories, particularly in the ranges of "≥ 0 and < 0.5 K €" (10,929 recipients, 19,96%) and "≥ 0.5 K and < 1.25 K €" (17,892 recipients, 32,67%). Slovenia has very few recipients in the higher direct aid categories, with only three recipients receiving subsidies of "≥ 500 K €".

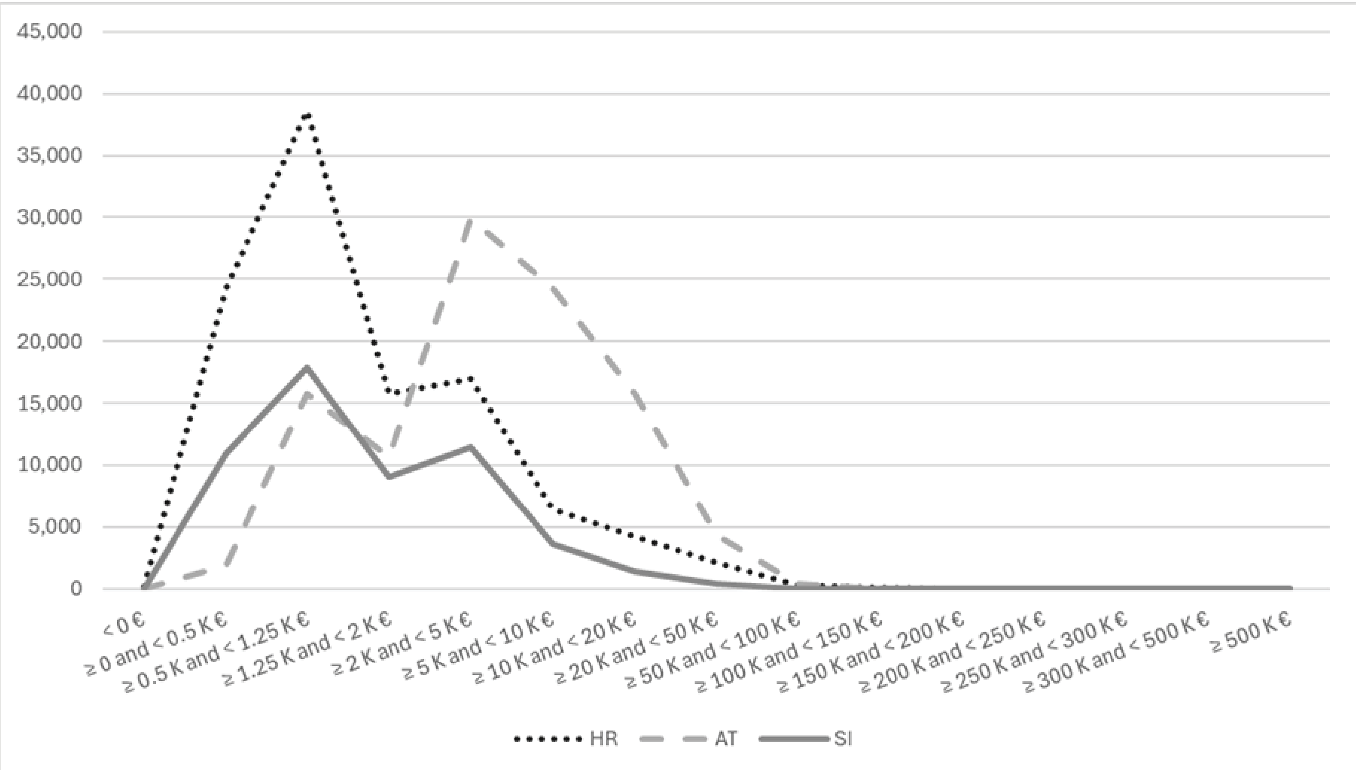

Figure 1. Distribution of direct aids to the producers - Financial year 2022, Number of beneficiaries per range of expenditure in Croatia, Slovenia and Austria

Source: Table 1

Key differences and observations reveal that Croatia has the highest total number of direct aid recipients, followed by Austria and Slovenia, indicating a broader distribution of subsidies in Croatia. All three countries show a significant concentration of recipients in the lower direct aid categories, suggesting that many small-scale farmers benefit from these subsidies. However, Austria stands out with a relatively higher number of recipients in the "≥ 2 K and < 5 K €" category compared to Croatia and Slovenia. Additionally, the number of recipients in the higher direct aid categories (≥ 50 K € and above) is very low across all three countries, indicating that large-scale farms receiving substantial subsidies are rare.

Overall, the Figure 1 highlights that most agricultural direct aid recipients in these countries fall within the lower financial brackets, with a sharp decline in the number of recipients as the direct aid amount increases. This distribution pattern is consistent across all three countries.

CONCLUSIONS

This study investigates the association between direct aid inequality and agricultural productivity within the European Union by employing the Gini coefficient as a measure of inequality in direct aid distribution, along-side various productivity indicators. The results demonstrate significant negative correlations between the Gini coefficient and both output per agricultural work unit and gross value-added per agricultural work unit, indicating that a more equitable distribution of subsidies could enhance productivity per unit of work.

Although the analysis highlights certain patterns in the distribution of payments relative to productivity, it is important to emphasize that these relationships are influenced by a range of additional factors, including production structure, farmers' qualifications, the strength of agri-food chains, and the broader economic context. These aspects further complicate the issue of fairness and efficiency within the CAP. Particularly noteworthy is the growing debate in scientific and professional literature on income equality per unit of labour, even though this is not an official CAP criterion.

These results highlight the complex relationship between the direct aid distribution and agricultural productivity. The significant negative correlations between the Gini coefficient and both OUTPUT/AWU and GVA/AWU suggest that a more equitable direct aid distribution can enhance productivity per unit of work. However, the mixed results for the OUTPUT/UTILISED AREA and GVA/HA indicate that other factors, such as land management practices and regional agricultural policies, also play crucial roles.

The distribution patterns observed in the three EU members comparative analysis of direct aid distribution reflect the broader context of agricultural direct aid policies in the EU. The concentration of recipients in lower direct aid categories highlights the support provided to small and medium-sized farms, which are crucial for rural development and sustainability. The limited number of recipients in the higher direct aid categories suggests that large-scale farms, while fewer in number, may receive a disproportionate share of total subsidies, contributing to income inequality within the agricultural sector.

This study provides valuable insights into the relationship between direct aid distribution inequality and agri-cultural productivity in the EU. However, some limitations should be noted. The analysis is based on data from a single financial year (2022), which may not capture longer-term trends or account for year-to-year fluctuations in agricultural conditions and policies. A multi-year analysis would provide a more robust understanding of these relationships over time. Additionally, exploring alternative inequality metrics beyond the Gini coefficient could offer a more nuanced perspective on subsidy distribution complexity. Future research in this area would contribute to a deeper understanding of the dynamics between subsidy distribution and agricultural productivity in the EU context.

In conclusion, our findings underscore the importance of equitable direct aid distribution in promoting agricultural productivity. Policymakers should consider these dynamics when designing direct aid frameworks, to ensure that subsidies effectively enhance productivity and support sustainable agricultural development.

REFERENCES

Biagini, L., Antonioli, F. and Severini, S. (2023). The impact of CAP subsidies on the productivity of cereal farms in six European countries: A historical perspective (2008–2018). Food Policy 119: 102473.

European Commission. (n.d.a). CAP performance 2014–20. European Union. Retrieved May 5, 2025, from https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cmef/cap-performance-2014-20_en

European Commission. (n.d.b). Common Agricultural Policy Farm Income Dashboard. Retrieved May 5, 2025, from https://agridata.ec.europa.eu/extensions/DashboardIndicators/FarmIncome.html

European Commission. (2024). Direct aid breakdown. Distribution of direct aid to farmers – indicative figures 2022 financial year. European Union. Retrieved May 5, 2025, from https://agriculture.ec.europa.eu/common-agricultural-policy/financing-cap/beneficiaries/direct-aid-breakdown_en

Eurostat. (2025). Economic accounts for agriculture - values at current prices [aact_eaa01]. European Commission. Retrieved from https://ec.europa.eu/eurostat/databrowser/product/page/aact_eaa01

Kumbhakar, S. C. and Lien, G. (2010). Impact of subsidies on farm productivity and efficiency (pp. 109–124). Springer New York.

Dinis, I. (2024). Examining disparities in common agriculture policy direct payments among farming systems: Evidence from Portugal. Agricultural Economics 12(7).

Garrone, M., Lee, H., Olper, A., Emmers, D. and Swinnen, J. (2019). Subsidies and agricultural productivity in the EU. Agricultural Economics 50(6): 803–817.

Goyal, A. and Nash, J. (2017). Reaping richer returns: Public spending priorities for African agriculture productivity growth. Washington DC: World Bank; Agence Française de Développement.

Mamun, A. (2024). Impact of farm subsidies on global agricultural productivity. Agricultural Economics 55(2): 346–364.

Sadłowski, A., Beluhova-Uzunova, R., Popp, J., Atanasov, D., Ivanova, B., Shishkova, M. and Hristov, K. (2022). Direct payments distribution between farmers in selected new EU member states. AGRIS online Papers in Economics and Informatics, 14(4). Czech University of Life Sciences Prague, Faculty of Economics and Management.

Severini, S. and Tantari, A. (2015). Which factors affect the distribution of direct payments among farmers in the EU member states? Empirica 42(1): 25-48.

Sinabell, F., Schmid, E. and Hofreither, M. (2013). Exploring the distribution of direct payments of the common agricultural policy. Empirica 40(2): 325-341.

Vollrath, D. (2007). Land distribution and international agricultural productivity. American Journal of Agricultural Economics 89(1): 202-216.

Economics of Milk Production on Permanent Grassland in Mountainous Areas

Jaka Žgajnar, Stane Kavčič and Marija Tomšič

Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana, Slovenia, (jaka.zgajnar@bf.uni-lj.si)

ABSTRACT

This paper presents an economic analysis of dairy farms located in the western region of Slovenia, an area characterized by permanent grassland and natural constraints (LFA), which result in limited production conditions and lower labour productivity. Based on three typical agricultural holdings of varying sizes, the study evaluates economic performance using the SiTFarm model. Key indicators such as gross margin, labour productivity, and greenhouse gas emissions are assessed. Results confirm that herd size and milk yield significantly influence economic sustainability, with larger farms generally performing better despite lower productivity per cow. Improving milk yield by 1,000 kg per lactation has a notably positive impact on income and reduces emissions per unit of output. While small farms face economic challenges, milk processing emerges as a viable strategy to enhance their long-term sustainability. The findings underline the importance of targeted development strategies that consider both economic and environmental dimensions.

INTRODUCTION

The dairy sector is an important agricultural sector both in the EU and also in Slovenia. It represents a diverse group of farms that vary in terms of the number of dairy cows, the extent of cultivated land, location, as well as in farming technology and management practices. This paper analyses the economic performance of dairy farms located in the western part of Slovenia. This is a remote area characterized by a pre-dominance of permanent grassland within the agricultural land use structure. The region lies entirely within areas facing natural constraints (LFA), which translates into more challenging production conditions and lower labour productivity. The area is home to both small and large-scale farms engaged in milk production. The dominant dairy breed in the region is the Brown Swiss.

Both small and medium size farms are important from social as well as environmental perspective. As high-lighted by Borawski et al. (2020), an important characteristic of milk production is the existence of economies of scale. Small dairy farms are less competitive compared to larger ones. For later it is typical high level of labour productivity mainly due to favourable production potential (Poczta et al., 2020). However, opposite holds for small semi-subsistence and small farms, usually located in LFA region, that achieve much lower labour productivity. They have higher unit production costs in comparison to larger farms and are from economic perspective usually less efficient. On the other hand, this is a region where even medium farms tend to achieve somewhat lower milk yields, primarily due to the fact that the feeding ration is based on forage produced on permanent grassland, requiring the purchase of concentrate feed. Some of these farms are also involved in the processing of milk into dairy products, the other deliver milk into local dairy.

In the paper we present the economic outcomes of these farm types, exploring their performance and examining how moderately higher milk yields affect their overall economic viability. The analysis is conducted using the SiTFarm model a specialized farm model designed for conducting economic analyses at the farm level in Slovenia. SiTFarm has been applied in various studies of the agricultural sector, including the dairy sector (Žgajnar and Kavčič, 2024). It has been used as decision-support tool for policymakers and agricultural policy planners (Žgajnar et. al, 2023; Žgajnar, 2024). In this context, the model allows for analysis of market revenues and budgetary support payments, while also simulating variable costs, thereby enabling gross margin analysis. The model is based on a mathematical programming approach and utilises optimization capabilities, which support the balancing of material and nutrient flows within the farm system.

In the following sections, we briefly present the modelling approach and the characteristics of defined dairy farms for the analysed region. Then we summarize the results, focusing on key economic indicators under assumed production conditions. Special attention is given to the impact of increased milk yield on overall farm economics. The article concludes with key findings, highlighting the importance of herd size, productivity, and strategic development pathways.

MATERIAL AND METHODS

SiTFarm model

For the purpose of analysing dairy farms in Slovenia, utilising only permanent grassland in mountain LFA region, the SiTFarm tool (Slovenian Typical Farm Model Tool) was employed (Žgajnar et al., 2022). This tool represents a mathematical programming-based farm model that enables a wide range of analyses at the level of a farm's production plan. SiTFarm is structured modularly and integrates three distinct modelling approaches. The first component consists of static models of Typical Agricultural Holdings (TAHs), which represent various farming systems (production models) commonly observed in practice. Each production plan reflects the expected structure and output of a specific type of dairy farm, thereby serving as a representative model for a broader category of similar farms. The second modelling approach involves budget calculations (Model Calculations – MC), which serve as the primary source of economic and technological data at the level of individual production activities. These are static production models developed independently by the Agricultural Institute of Slovenia (AIS, 2025), covering all major agricultural activities including fodder production, cash crops, vegetable production, and livestock farming. MCs facilitate realtime adjustments of individual budgets in terms of production technology, intensity (yield), and price-cost ratios, aligning them with the conditions of the analysed typical farm. The third approach is a comprehensive farm model (FM) that integrates the two aforementioned approaches. It enables the autonomous calibration of production plans in accordance with technological parameters, as well as each farm's specific production constraints and resource endowments.

The version of SiTFarm applied in this study relies on mathematical programming. This allows for the use of various techniques in solving the production plan, which constitutes the basic analytical level. In this instance, deterministic linear programming was employed. The constructed matrix of production possibilities serves as a framework for production planning, with the primary objective being the maximization of Gross Margin (GM). However, it is important to note that this analysis does not aim to determine the optimal solution for each TAH. Rather, the objective is to reconstruct a production plan that reflects real-world conditions - plans that may diverge from the optimal allocation of resources due to numerous practical constraints. To this end, a "partial optimization process" was utilized - an extension of linear programming incorporating a complex system of equations. This approach facilitates the estimation of uncertain variables, enabling the development of a complete and technologically consistent production plan for a given farm.

Economic Indicators

The economic indicators presented are based on average input prices, hired labour costs, and average purchase prices from the year 2024. Market revenues represent the value of agricultural production sold, always calculated as final output at the farm level. In all analysed cases only primary production is assumed, and therefore, on-farm milk processing is not included in the analysis, although it may represent a significant potential revenue stream if implemented.

Budgetary support payments are based on the current Common Agricultural Policy (CAP) strategic plan in Slovenia for the programming period 2023–2027. These include direct payments and payments for farming in areas facing natural constraints (LFA). Direct payments considered in this analysis encompass non-production-linked support, specifically the Basic Income Support for Sustainability, Complementary Redistributive Income Support for Sustainability, and selected ECO-schemes, as well as coupled support payments for dairy cows in mountain areas. Where eligibility criteria are met, additional payments for animal welfare are also included. Environmental payments, however, are not considered in this particular analysis.

Variable costs are calculated in the manner to avoid duplication where market and non-market activities coexist on an individual farm (TAH). All costs except fixed costs are included, with herd renewal also classified as a variable cost. The magnitude of this cost depends on herd replacement rates and the effectiveness of farm management and is assigned as an input specific to each farm type (TAH).

The central economic indicator observed is Gross margin (GM), calculated as the difference between total revenue and variable costs. To facilitate comparison of economic performance between farms, GM per hour is also calculated. This does not refer to total available working hours on the farm, but rather to effectively utilized labour, estimated using standardized labour input models. These models calculate labour demand based on the type and scale of each activity included in the farm's production plan. Additionally, a 2–3% flat-rate increment is added to account for essential non-technical activities such as record-keeping and farm management, which are crucial for operation but not directly linked to production.

Environmental Indicators

For each typical farm (TAH), a set of simplified environmental indicators has been calculated to monitor the potential impacts of farming practices on climate, water, and soil, and indirectly also on biodiversity. These indicators are expressed per hectare of utilized agricultural area (UAA) or as a percentage of the UAA (Žgajnar et al., 2022).

Greenhouse gas (GHG) emissions are presented in kilograms of CO_2 equivalents. The GHG emissions indicator captures the emissions generated from livestock activities on the farm. Emissions from feed production (except grazing) and the application of livestock manure are excluded from this scope (Žgajnar et al., 2022).

Fuel consumption is reported as the amount of fuel used per hectare of UAA in crop production. This metric depends primarily on the crop type, cultivation methods, and a range of operational factors such as the power of machinery, type and size of implements, driving speed, and overall labour productivity (Žgajnar et al., 2022).

Typical Dairy Agricultural Holdings that farm on permanent grassland in LFA

The analysis includes three types of agricultural holdings commonly found in this region (Table 1). The pre-dominant category consists of numerous medium-sized farms (with 18 dairy cows), but there are also some larger farms by Slovenian standards (with 50 dairy cows) and a few very small farms (with 6 dairy cows) engaged in milk production. The intensity of milk production is below Slovenian average on most of these farms. However, in the medium and large size categories, there are instances of slightly higher milk yields. In all cases, the farms raise Brown Swiss dairy cattle. This is a dual-purpose breed with an emphasis on milk production. Due to the composition of the milk, this breed is particularly important for dairy processing and cheese production, which are typical for this Alpine region in Slovenia.

Table 1. Characteristics of analysed dairy TAHs, farming on permanent grassland in LFA

Production Activities	**TAH50_6000**	**TAH50_7000**	**TAH18_7000**	**TAH06_4500**	**TAH06_5500**
Livestock					
Dairy cows (no.)	50	50	18	6	6
Breeding heifers (no.)	15	15	5	2	2
Young fattened cattle (no.)	–	–	5	3	3
Milk yield (kg)	6,000	7,000	7,000	4,500	5,500
Cultivated Areas and Labor					
Permanent grassland (ha)	46	46	18	6	6
Own labor input (h)	4,008	4,172	2,880	1,662	1,700

The animals raised on these farms are of medium size, with an average weight of 650 kg, and their milk production ranges between 4,500 and 7,000 kg. This breed is known for its adaptability to harsh mountainous terrain and its excellent grazing efficiency, allowing it to make optimal use of local feed resources from permanent grassland. On all farms, in addition to home-grown fodder, a necessary portion of concentrated feed is purchased, as the farms lack the capacity to produce it themselves. All of the farms operate only on permanent grassland, where they produce hay and silage, and, with the exception of the smallest farms, often practice grazing for at least half of the year.

As a dual-purpose breed, male calves are usually fattened at home. This is generally the case on smaller and medium-sized farms, which still have the capacity to do so, while larger farms usually sell male calves. All farms, however, breed the majority of female animals needed for replacement from their own stock, with any surplus being sold on the market.

RESULTS

The results present the key economic outcomes for analysed TAHs (Table 2). The effect of increased milk production is also simulated for both the small (TAH_6) and large (TAH_50) farms.

The TAH case (TAH50_6000) represents larger farms that can be found in this area. Despite the large herd size (50 dairy cows), milk yield is relatively low (6,000 kg). This coincides with the LFA, where conditions for forage production are less favourable. The farm manages 46 hectares of permanent grassland. The herd of Brown Swiss cattle consists of 50 dairy cows and an appropriate number of breeding heifers. Male calves are sold before the age of 1 month.

During the growing season, animals graze (36% of UAA). On 43% of the land, grass silage is produced. The required hay is grown on remaining grassland. To meet the nutritional requirements of the animals, the farm purchases 41 tons of concentrated feed annually, mainly energy feed and some protein feed. For this level of production, 2.2 full time equivalent (FTE) are required.

The farm generates approximately 200,000 € annual revenue, of which 34% represents variable costs. The farm receives budgetary payments amounting to 12% of total revenue. Given the relatively high labour efficiency, the expected gross margin per hour (GM/h) is favourable and exceeds 32 €. However, it is true that the share of fixed costs on such a farm can be high, which significantly reduces the income hourly rate. Nevertheless, such a farm is very promising in terms of development, provided it has interested successors. Speculatively, milk processing could be an interesting supplementary activity if enough labour is available. It could potentially be expanded gradually, depending on the farm's capacity and its ability to secure a sufficiently large consumer base for dairy products.

From an environmental perspective, the farm has a slightly larger carbon footprint in terms of equivalent CO_2 emissions, and it is somewhat above average in this regard. However, it does not represent a major environmental burden.

If the milk yield were hypothetically increased by 1,000 kg per cow (TAH_50_7000), this would result in a significant positive impact on economic indicators (Table 2). The expected feed requirements would slightly change, with less grazing and a 68% increase in the purchase of concentrated feed. This would significantly increase variable costs by about 16%. The increased milk production would raise market revenues by approximately 13%, positively affecting GM, which would exceed 144,000 € annually. Of course, such a change would require more labour (+4%), resulting in a 5% increase in the GM hourly rate. The higher milk yield would significantly reduce CO_2 emissions per kg of milk produced (nearly -11%). Overall, the results for this farm are very favourable, and it can undoubtedly be ranked among the top quartile of the most successful dairy farms in Slovenia.

The second case (TAH18_7000) involves a medium-sized farm, which raises 18 Brown Swiss dairy cows and achieves a milk yield of 7,000 kg. The farm breeds its own heifers for replacement and also raises some male calves for fattening. The farm manages 18 hectares of permanent grassland located in LFA. Grazing accounts for 30% of the land, with more than 50% dedicated to grass silage production, and approximately 14% is used for hay production. To meet the nutritional needs, the farm purchases 26 tons of concentrated feed, which represents an additional cost. Model calculations estimate that the farm requires 1.6 FTE of family labour.

Table 2. Economic and environmental indicators for analysed dairy TAHs

	TAH50_6000	TAH50_7000	TAH18_7000	TAH06_4500	TAH06_5500
Economic Indicators					
Revenue (EUR)	200,460	224,092	88,714	23,456	26,931
Market revenue (EUR)	176,580	200,365	79,316	21,136	23,990
Budgetary subsidies (EUR)	23,880	23,727	9,399	2,320	2,940
Variable costs (EUR)	68,381	79,619	30,309	10,549	12,051
Gross margin (EUR)	132,079	144,473	58,405	12,907	14,879
Gross margin per hour (EUR/h)	32.95	34.63	20.28	7.77	8.75
Environmental Indicators					
Emission intensity – milk production (kg CO_2-eq/kg of milk)	0.789	0.705	0.573	0.791	0.68
Emission intensity – beef production (kg CO_2-eq/kg of meat)			5.98	5.98	5.98
Livestock density (LU/ha)	1.27	1.28	1.34	1.55	1.5
Mineral fertilizer use per ha (kg/ha, NPK 15:15:15 eq)	213	210	210	187	187
Fuel consumption (l/ha)	96	101	112	119	118

With this scale of production, the farm generates 88,714 € revenue, of which approximately 10% is from budgetary payments (direct payments, including coupled support, LFA payments, and smaller amounts also from one-year ECO schemes and Animal Welfare Payments). Per hectare of cultivated land, this amounts to 524 €.

Variable costs for this farm in total are approximately 30,000 €, which represents 38% of market revenue or 34% of total revenue. GM is relatively favourable, amounting to 58,405 € annually, and when converted to effective working hours, the hourly rate is 20.28 €. This hourly rate places the farm within the above-average range for the dairy sector in Slovenia. To obtain a complete picture of the economic performance, fixed costs should be considered, which ultimately results in a considerably lower income. This farm has some potential for development, and one possible avenue is in dairy processing. From an environmental perspective, the farm's practices are considered favourable, and no significant challenges are foreseen.

The final case (TAH6_4500) represents a smaller dairy farm, one of the types that are gradually disappearing. It is also a type of farm where we often see a transition to family milk processing. This farm raises Brown Swiss cattle in a relatively extensive manner, with milk production of only 4,500 kg per cow. The farm breeds the necessary number of heifers and fattens beef cattle. The farm operates nearly 6 ha of permanent grassland, all within LFA.

On this farm, the animals are not grazed but are kept in the barn year-round, following a tied-in housing system. About 80% of the feed is silage, with the remainder being dried and made into hay. To meet the animals' nutritional needs, the farm purchases approximately 8 tons of concentrated feed. For this level of production, the farm requires just under 1 FTE. The farm's has a stocking rate of 1.55 livestock units per hectare.

This farm generates just over 21,000 € in annual revenue from milk production. Budgetary payments are also important, accounting for about 10% of total revenue. The share of variable costs is high, at 50% of total revenue, resulting in a modest gross margin of 7.77 € per hour. This farm is definitely in need of a new strategy for long-term sustainability. From an economic perspective, this farm is often not viable, and milk processing could be an opportunity for its survival and continued operation. Environmentally, this type of farming is somewhat less favourable, primarily due to the feed ration and the low milk production per cow.

If the milk yield on this farm were increased by 1,000 kg per cow (TAH6_5500), the farm would need to produce more high-quality grass silage and purchase more than double the amount of concentrated feed. Higher milk production would increase revenue by nearly 15%, and variable costs would rise by nearly the same percentage. This would positively impact gross margin, which would increase by 15%. Due to the additional labour required, the hourly rate would improve slightly, by just under 1€. The improved milk yield would result in better environmental indicators, particularly in terms of CO_2 equivalents, while other indicators would remain relatively unchanged.

CONCLUSIONS

As the results indicate, the scale of production has a predictable impact on the economic performance of dairy farms. Despite somewhat lower milk yields, the Brown Swiss breed is undoubtedly a suitable choice due to its efficient use of local feed resources. This is particularly relevant, as farms in the studied area typically operate solely on permanent grassland in mountainous regions.

In spite of the challenging production conditions, medium-sized and especially larger farms can achieve solid economic results. Based on the outcomes, the representative of the larger farm type is positioned in the top quartile of dairy farms in Slovenia. In contrast, small to medium-sized farms face the challenge of identifying viable strategies to ensure economic sustainability. Nonetheless, they are of high significance from both environmental and social sustainability perspectives. Small farms, however, are under considerable pressure in terms of all three pillars of sustainability economic, environmental, and social.

Moreover, the results demonstrate that, in addition to farm size, milk yield significantly influences economic outcomes. It is, therefore, a crucial factor for improving profitability and should be a primary focus for farms currently achieving lower yields. Although increased production typically results in higher costs, particularly for concentrated feed, these expenses are economically justified and can be offset by the additional revenue generated from increased output.

Value-adding strategies such as on-farm milk processing would undoubtedly enhance economic indicators. This option may be especially relevant for medium-sized, and in some cases also small farms, as it could substantially improve economic sustainability. However, such diversification requires investment, raising critical questions about how to secure funding, implement the necessary infrastructure, and address challenges related to marketing, consumer demand, technical knowledge, and labour availability. One potential strategy is certainly the cooperation and integration of these farms. This could indeed represent a valuable direction for further research.

ACKNOWLEDGEMENTS

The research was financially supported by the project CRP V4-2402, funded by Ministry of Agriculture, Forestry and Food of Slovenia and the Slovenian Research Agency.

REFERENCES

AIS (2025). Agricultural Institute of Slovenia. Model Calculations. Available online: https://www.kis.si/en/Model_Calculations_OEK/

Bórawski, P, Pawlewicz, A., Parzonko, A., Harper, J.K. and Holden, L. (2020). Factors Shaping Cow's Milk Production in the EU. Sustainability 12: 420.

Poczta, W, Średzińska, J. and Chenczke, M. (2020). Economic Situation of Dairy Farms in Identified Clusters of European Union Countries. Agriculture 10: 92.

Žgajnar, J. and Kavčič, S. (2024). Understanding the Dairy Sector in Slovenia: A Modeling Approach for Policy Evaluation and Decision Support. Sustainability 16(14): 6009.

Žgajnar, J., Kavčič, S., Tomšič, M., Zagorc, B. and Brečko, J. (2023). Analysis of the impacts of CAP changes between the periods 2014–2022 and 2023–2027 on climate change, the environment, and the economics of agricultural holdings using the farm model for Slovenia. Ljubljana. (In Slovene)

Žgajnar, J., Kavčič, S., Tomšič, M., Zagorc, B., Brečko, J., Hiti Dvoršak, A., Moljk, B., Verbič, J., Bedrač, M., Kožar, M., Cunder, T. and Jerič, D. (2022). Development of a model for systematic monitoring of the economic situation and analysis of agricultural policy impacts at the level of typical farms: Final report. Ljubljana: Biotechnical Faculty, February 2022. 437 pages. (In Slovene)

Žgajnar, J. (2024). Using a farm model to support agricultural policy, an example of dairy farms. V: Resilience through innovation: conference proceedings – academic: 24th Congress of the International Farm Management Association, Saskatoon, Saskatchewan July 7-12, 2024. pp. 325-337.