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ASSESSING THE AGRO-ECOSYSTEM PERFORMANCE IN A LONG-TERM WINTER WHEAT CROPPING*

DRAGIŠA MILOŠEV, SRĐAN ŠEREMEŠIĆ, IVICA ĐALOVIĆ, BORIVOJ PEJIĆ, VLADIMIR ĆIRIĆ[1]

SUMMARY: The aim of this study was to access the impact of agricultural practices to the multiple agro-ecosystem function of winter wheat cropping systems. The data were obtained from a long-term experiment at the Rimski Šančevi experimental station of the Institute of Field and Vegetable crops. A simple performance-based index was used to discriminate among treatments based on the crop and soil parameters within the different agro-ecosystems. The following indices were used: food production, raw material production, nutrient cycling and greenhouse gas regulation. Continuous cropping resulted with decrease in the utilization of the agro-ecological potential. Our results indicate that the soil have lost productivity and quality, irrespective to the applied cropping practices. Accordingly, it was found that yield variation resulted mostly from unfavorable climate condition, thus fertilization had the essential effects on yield preservation. At the end of the investigated period 3-year rotation has highest utilization of the inherent soil productivity in comparison with investigated wheat-based cropping systems.

***Key words**: agro-ecosystem performance, grain yield, winter wheat, cropping systems.*

INTRODUCTION

Agricultural practice determines the level of food production that imposes significant influence on the state of the global environment. The long-term environmental sustainability of the food and feed production is one of the major questions facing modern agriculture (Javadzadeh, 2014). Assessing the environmental sustainability of agricultural

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[1]Dragiša Milošev, PhD, full professor, Srđan Šeremešić, PhD, assistant professor, Borivoj Pejić, PhD, associated professor, Goran Jaćimović, PhD, assistant professor, Vladimir Ćirić, PhD, assistant, University of Novi Sad, Faculty of Agriculture, R. Serbia, Ivica Đalović, Institute of Field and Vegatable Crops, Novi Sad Serbia
Corresponding autor: Dragiša Milošev, Email: mildr@polj.uns.ac.rs, Phone:+381214853444.
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systems in a quantitative manner requires the identification and integration of diverse phenomena of 'indicators' of environmental effects, in a framework consistent with the evolving concept of sustainability (Sands and Podmore, 2000). Agro-ecosystems are highly complex and cropping systems perform multiple functions in their role as agro-ecosystems. Regarding agro-ecosystem performance as food and raw materials production, nutrient cycling, erosion control, greenhouse gas regulation, water regulation and waste treatment are main indices of agro-ecosystem management. Indices are tools for aggregating and simplifying information of a diverse nature into a useful and more advantageous form (Sands and Podmore, 2000). A simple performance-based index was developed to determine the relative sustainability of agricultural management system within the context of multiple agro-ecosystem functions and to give users a simple measure to assess sustainability of agricultural practices. Winter wheat cropping could provide a basis for evaluating the relationship between environment and yield performance in the investigated long-term trail as it has not undergone significant change over the years compared with other crops. In addition to that, winter wheat is a versatile crop that can be successfully grown under many environmental conditions with contrasting agronomical inputs as one of the most adapted crops (Chloupek et al., 2004). The aim of this study was to evaluate the winter wheat cropping with performance based index.

MATERIALS AND METHODS

The present study was performed on the long–term experiment (LTE) "Plodoredi" carried out at the Rimski Šančevi Experimental Field of the Institute of Field and Vegetable Crops in Novi Sad (45° 19' N, 19° 50' E, 84 m). The trial was established 1946/4 in order to improve production and conservation properties of chernozem, in 1970 different systems of crop production were introduced in order to examine their effect on yield of most important crops in Vojvodina (Milošev, 2000; Šeremešić et al., 2011).

The study treatments were:

1. 3–year crop rotation (maize-soybean-wheat), mineral fertilizer 100 kg N ha^{-1}+ crop residues (D3)
2. 2–year crop rotation (maize-wheat), mineral fertilizer 100 kg N ha^{-1}+crop residues (D2)
3. Monoculture (wheat-wheat), mineral fertilizer 100 kg N ha^{-1}+crop residues (MO)
4. 2–year rotation (maize-wheat), without fertilizers+crop residues (N2)
5. 3–year rotation (maize-soybean, soybean-wheat), without fertilizers+crop residues (N3)

For this study we used dataset of a treatments from the long-term experiment from 2000 to 2010 year. The counting of index is led by four basic steps: data grouping, calculation of averages, ranking and scoring treatments, and summing of scores within and across agro-ecosystem functions.

Step 1: Group Data within Agro-ecosystem Functions

Agro-ecosystem functions could be presented with appropriate indicators. The procedure is initiated by surveying the dataset for indicators that could be grouped within agro-ecosystem functions (Liebig et al., 2001). According to Constanza (1997) for the purpose of analysis, ecosystem services are grouped into 17 major categories. The analysis considered the entire system, but we used four of them: food production, raw material production, nutrient cycling and greenhouse gas regulation. The food production as the first ecosystem service provides major portion of gross primary production extractable as food. The second ecosystem service is raw materials with ecosystem functions which includes that portion of gross primary production extractable as raw materials. The third ecosystem service is nutrient cycling with ecosystem functions-storage, internal cycling, processing and acquisition of nutrients. The fourth agro-ecosystem included in this paper is greenhouse gas regulation. Within each agro-ecosystem, indicators are selected to characterize the performance of that function (Liebig et al., 2001).

[**Agro-ecosystem performance** $= f$ Food production X $W_{fp} = f$ (grain yield, grain N content), Raw materials production X $_{rmp} = f$ (stover yield, stover N content), Nutrient cycling X $W_{nc} = f$ (residual soil NO_3, soil pH), Greenhouse gas regulation X $W_{ggr} = f$ (soil organic C, early spring soil NO_3)]

Where W_{fp}, W_{rmp}, W_{nc}, W_{ggr} are the relative weights. Consequently, the relative weights may be adjusted for each function to account for differences in the number of indicators among functions (Liebig et al., 2001).

Step 2: Calculate Treatment Averages

This step contains calculation of treatments averages for each indicator. It is important to make a difference between indicators, because some of them are best evaluated over time, whereas the others are cumulative in their influence on agro-ecosystem functions, increasing or decreasing over time (Table 1.).

Table 1. Different cropping systems averages for indicators used to represent agro-system functions.

	Cropping system				
Agro-ecosystem indicators	D2	D3	MO	N2	N3
Food production					
Grain yield, kg/ha	5088	6086	4625	1102	1730
Grain N content, g/kg	98.82	118.61	90.18	19.21	31.19
Raw meterials production					
Stover yield, kg/ha	5972	8699	6108.2	1340	2566
Stover N content, g/kg	9.8	11.8	9.01	1.9	3.1
Nutrient cycling					
Residual soil NO3-N, 0-90 kg/ha	116	120	100	45.5	48.5
Soil pH	7.17	7.43	7.11	7.50	7.60
Greenhouse gas regulation					
Soil organic C, kg/ha	60 200	63 850	64 750	50 820	51 320
Early spring soil NO3-N, kg/ha	24.9	22	20	11.5	15

Step 3: Rank and score treatments

According to Liebig (2001) treatment values are ranked for each indicator in ascending or descending order, depending on whether a higher value for the indicators are good or bad, or in simply terms good or bad criteria. After the treatment values are ranked, they are scored based on their relative differences from the optimal value. The most straightforward approach from data arranged in descending order it to assign a score of 1.0 to the highest treatment (Table 2.)

Table 2. Rank and score treatments for indicators within agro-ecosystem functions

Rank	Treatment	Score	Rank	Treatment	Score
Food production					
	Grain yield			Grain N content	
1	D3	1.00	1	D3	1.00
2	D2	0.84	2	D2	0.83
3	MO	0.76	3	MO	0.76
4	N3	0.28	4	N3	0.26
5	N2	0.18	5	N2	0.16
Raw materials production					
	Stover yield			Stover N content	
1	D3	1.00	1	D3	1.00
2	MO	0.70	2	D2	0.86
3	D2	0.68	3	MO	0.76
4	N3	0.29	4	N3	0.26
5	N2	0.15	5	N2	0.16
Nutrient cycling					
	Residual NO_3-N			Soil pH	
1	N2	1.00	1	N3	1.00
2	N3	0.94	2	N2	0.98
3	MO	0.45	3	D3	0.97
4	D2	0.39	4	D2	0.94
5	D3	0.37	5	MO	0.93
Green house regulation					
Soil organic C - Early spring soil NO_3					
1	MO	1.00	1	N2	1.00
2	D3	0.97	2	N3	0.76
3	D2	0.91	3	MO	0.57
4	N3	0.78	4	D3	0.52
5	N2	0.77	5	D2	0.46

Step 4: Sum scores within and across agro-ecosystem functions

Upon summing scores within agro-ecosystem functions, the remaining step is to sum scores across functions. The final score would reflect a relative ranking of agro-ecosystem performance among treatments for functions included in the procedure (Table 3.).

RESULTS AND DISCUSSION

Quantifying the effects of management practices against agro-ecosystem functions is necessary to determine the sustainability of copping systems (Liebig and Varvel, 2003). The overall agro-ecosystem performance score for the D2 is 84.42, for D3 is 97.57, as a highest, for MO 84.71, and for N3 62.43 and for N2 is 54.57 as the lowest. Based on the observed results crop yield as well as raw material production have higher difference of min. and max values, compared with the nutrient cycling and greenhouse gases regulation. Winter wheat monoculture has showed higher sustainability compared with N2, N3, D2 that indicated its positive contribution to a nutrient cycling and greenhouse gas regulation. However this can be described as cumulative effects of the long-term experiment. Increased productivity of D3 cropping system is based upon effects of 3-year rotation that in the long-term increases winter wheat yields. Raw material ($r = -0.88$) has significantly negative effects whereas nutrient cycling and greenhouse gases showed higher correlation with the agro-ecosystem performance (Table 3.). Also, food production (yield level) showed positive effects on agroecosystem performance. On the basis of the obtained results we anticipate that cropping systems with most effects on environmental condition are not those with the higher agro-ecosystems performance.

Table 3. Agro-ecosystem performance (AESP) scores for different winter wheat cropping systems

Agro-ecosystem function					Agro-ecosystem performance scores	
Treatments	Food production	Raw materials production	Nutrient cycling	Greenhouse gas regulation	Not scaled	Scaled to 100 (7=100%)
D2	1.67	1.54	1.33	1.37	5.91	84.42
D3	2.00	2.00	1.34	1.49	6.83	97.57
MO	1.52	1.46	1.38	1.57	5.93	84.71
N2	0.34	0.31	1.94	1.23	3.82	54.57
N3	0.54	0.55	1.98	1.30	4.87	62.43
Correlation to AESP	0.82	-0.88	0.96	0.97	-	-

CONSLUSIONS

This study showed that simple performance-based index is helpful tool in discriminating differences of agro-ecosystem performance between contrasting management systems in long-term winter wheat copping system. Long-term cropping has resulted in differences in soil organic carbon, soil pH and temporal soil NO_3. However, properly managed agro-ecosystems were capable to resist the pressure and responded with resilience to applied cropping technology over the years. Accordingly, it was found that yield decline resulted mostly from unfavorable climate condition and fertilization had the essential effects on yield preservation. At the end of investigated period three-year rotation (D3) had highest utilization of the inherent soil productivity compared with the unfertilizated plots (N3).

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PROCENA PERFOMANSI AGROEKOSISTEMA U VIŠEGODIŠNJEM OGLEDU SA PŠENICOM

DRAGIŠA MILOŠEV, SRĐAN ŠEREMEŠIĆ, IVICA ĐALOVIĆ,
BORIVOJ PEJIĆ, VLADIMIR ĆIRIĆ

Izvod

Cilj ovog istraživanja je bio da se utvrdi uticaj sistema gajenja pšenice na pokazatelje performansi agroekosistema: prinos, proizvodnja biomase, kruženje hraniva i regulacija gasova staklene bašte. Analizirani su višegodišnji eksperimenti na Rimskim Šančevima. Dugogodišne korišćenje zemljišta u poljoprivredne svrhe uticalo je na promene u prinosu i pad produktivnosti zemljišta. Utvrđeno je da tropolje (kukuruz-soja-pšenica) ima najbolje korišćenje proizvodnih uslova i najmanje negativno delovanje na stanje životne sredine. Kvalitativni pokazatelj kao što je "analiza performansi" može uspešno da se koristi prilkom opisivanja funkcija agroekostistema u našim uslovima.

Ključne reči: performanse agroekosistema, prinos, ozima pšenica, sistemi ratarenja

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