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Crop Rotation Practiced by Romanian Crop Farms before the Introduction of the "Environmentally Beneficial Practices Applicable to Arable Land" Eco-Scheme

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Abstract: The main objective of this article is the analysis of crop rotation applied to three crop farms of different sizes in Romania. The period under study is before the implementation of the "Environmentally beneficial practices applicable to arable land" eco-scheme, included in the National Strategic Plan of Romania, 2023–2027, in the section on direct payments related to subsidies. The analysed crop farms have different areas, as follows: Farm A—64.97 ha, Farm B—615.50 ha and Farm C—2881.33 ha. This research aims to highlight the agro-environmental conditions specific to each farm that are required to be met by 2023. The data analysis highlights the fact that farms under 100 ha, such as Farm A, must apply the conditions of the eco-scheme as follows: 3.25 ha with non-productive elements, including uncultivated land; 6.50 ha cultivated with crops from the Leguminosae family, 16.25 ha cultivated with cereals, 19.49 ha cultivated with corn, 12.99 ha cultivated with sunflowers, 3.25 ha cultivated with watermelon and 3.25 ha cultivated with vegetables. These farms do not apply modern technologies and have fragmented surfaces, and must have both uncultivated areas and areas planted with nitrogen-fixing crops, but must also practice crop diversification. Farms of over 100 ha, such as Farm B, must have 30.78 ha of non-productive elements and 246.20 ha cultivated with crops from the Leguminosae family, of which 30.78 ha are perennial crops and 215.42 ha are annual crops, such as soy. Crop diversification is also recommended, with 92.33 ha cultivated with cereals, 184.65 ha cultivated with corn and 61.55 ha cultivated with oil crops, sunflower and/or rapeseed. Farms the size of Farm C must have 144.07 ha of non-productive elements, 720.33 ha must be cultivated with crops from the Leguminosae family, such as soy, and diversify crops as follows: 720.33 ha—cereals, 720.33 ha—corn, 518.64 ha—sunflower and/or rapeseed and 57.63 ha—potatoes.

Keywords: crop rotation; diversification; eco-scheme; protein crops; large crop farms

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1. Introduction

Considering the introduction of the "Environmentally beneficial practices applicable in arable land" eco-scheme applicable from 2023 in the National Plan of Romania for the 2023–2027 period, the research on the possibility of applying the conditions imposed by this measure to farmers who own more than 10 ha of arable land are missing or incipient. Therefore, this study brings to the fore the technological practices that these farms already comply with and the efforts of planning, implementing and continuously applying the aforementioned eco-scheme conditions. The further major advantages of this study aim at practising soil management appropriate to differently sized farms, which is optimal

for the requirements of the eco-scheme, and using environmentally friendly technological agricultural practices that will bring benefits to soil, water, atmosphere, crops and the environment, which are affected by some non-compliant practices. Soil fertilization is a universal solution that eliminates many of the problems encountered on agricultural land, but given the economic advantages of certain crops, it is often neglected. Climate extremes are expected to increase in intensity and become more frequent [1], and this may lead to increased drought in many regions of the world. In this situation, the combined effects of fertilization and irrigation are essential [2]. The increasingly frequent droughts of recent years, however, have brought to the fore a solution with favourable results from which differently sized crop farms can benefit after implementing it. Crop rotation is an important lever in increasing soil fertility and agricultural production; it is essential and cannot be replaced by other means. Consequently, sustainable agriculture must be based on correct and strict crop rotation rules, in accordance with the recommendations of specialists [3]. From an economic point of view, it requires the smallest financial investment and can be put into practice by cultivating agricultural crops on both small and large areas, and can lead to the profitability of crop farms of different sizes. As climate change increases in severity and frequency, farmers are urged to adapt [4]. Maintaining soil quality is a topical issue and can be achieved by preserving and improving fertility. It is considered as the key solution for any agricultural system, including sustainable agriculture. Soil fertility is determined by the influence of three essential factors: crop rotation, technological work carried out, and fertilization applied to the soil. Crop mapping based on satellite data on a regular basis and the production of accurate crop maps are essential for the analysis of technological schemes [3]. The conditions included in the "Environmentally Beneficial Practices on Arable Land" eco-scheme [5] refer to the introduction of environmentally beneficial farming practices in the activity of the farms concerned by this subsidy, some of which are general and compulsory, others specific and optional. The first mandatory condition refers to the existence of uncultivated areas on farms, set as a percentage of the total arable area. The non-productive elements (uncultivated land) need to account for 5% of the existing area, a measure that will apply from 2024. The problem of soil fertility can be solved by a rational combination of fertilization systems and technology applied to the soil. We define the soil as the division of the land of differently sized farms into plots that are as equal as possible to each other, the number of plots being equal to the number of years of rotation, and within these plots the crops must be distributed in time and space considering the tillage system, soil fertility and soil moisture. Crop rotation, a promising agricultural practice, leads to strengthening key elements of biodiversity, reducing the attack of diseases and pests, and stabilizing the production function of the ecosystem over time [6], preserving moisture, reducing crop weeds, achieving high yields and increased economic efficiency with reduced expenses and consumption, using agricultural machinery with maximum productivity, preventing and combating soil erosion, soiling and depletion in irrigation systems and stabilizing soils in order to ensure knowledge of the history of each soil so that farmers can know what happens in the soil after each crop in rotation from one year to the next. Authorities need to develop standards to support crop rotation technologies and prevent the problem of over- and under-subsidization [7]. However, from an economic point of view, land consolidation leads to a reduction in personnel costs, in the cost of consumables, such as fertilizers and plant protection products, in fuel costs, and in maintenance and repair costs of machinery by avoiding premature wear and tear, all of which can be achieved by consolidating isolated plots into compact land masses, reducing the time and distance spent on empty trips by aggregates and means of transport. Another compulsory measure from the eco-scheme refers to the introduction of protein crops the annual crop plan (10% of the area in 2023 and 5% in 2024). Protein crops that can be established are soybean, peas, field peas, asparagus, clover, field bean, chickpea, lupine, lentil, alfalfa, peanuts, legume mixtures, and perennial grasses. Another mandatory condition from the eco-scheme is that 85% of the area should be covered during the agricultural year (including the 15 June to 15 October period) with agricultural crops or

the remaining stubble after harvesting, or with some secondary crops, green cover crops, or newly established autumn crops after the main crop harvesting. It is imperative to also mention the economic aspect, because rigorous land management leads to an increase in turnover through the production gains achieved by making the best use of different categories of land under the same relief, soil, and microclimate conditions. In arable farming, the aim is to optimize the crop structure as follows: 25% cereals, 25% maize, 25% grain legumes (soybean, peas, beans, etc.) and sunflower, 25% fodder crops (alfalfa, clover, peas, etc.) so as to increase soil fertility and reduce the need for fertilizers and plant protection products, leading to lower production costs and higher quality of the products and thus higher income generated by their sale. This "Environmentally beneficial practices applicable to arable land" eco-scheme introduced in the National Strategic Plan of Romania [5] is destined for farms of more than 10.01 ha, which can benefit from an annual payment on the area of arable land owned. It also includes specific conditions that farms can choose from, including crop diversification: in farms with an area between 10.01 and 30 ha, there must be at least two agricultural crops, out of which the main crop must not exceed 75% of the area between May and September. In farms larger than 30 ha, diversification implies a minimum of three crops, out of which the main crop must not exceed 70% of the arable area of the farm and two crops must not exceed 85%, which is required for crop planning on agricultural land while taking into account the main factors affecting crop yields [8]. The diversified crop rotation can help improve the stability of the cropping system, and in the presence of extreme weather, a robust agricultural ecosystem can reduce pressure and resist uncontrollable weather and organisms [9].

The main agricultural crops are any of the various species defined in the botanical classification of crops: Brassicaceae, Solanaceae, and Cucurbitaceae families, fallow land or land cultivated with grasses or other herbaceous forages. Other specific conditions are the practice of conservation agriculture on 50% of the arable area: no tillage, strip tillage, or no-minimum-strip tillage. No tillage refers to sowing without prior preparation of the soil; strip tillage refers to sowing in prepared strips without intervention on the interval between rows, and minimum tillage concerns sowing after a superficial preparation of the soil without turning the furrow. Farms that qualify for this subsidy may also choose to plant two trees of the following species per hectare: apple, peach, plum, cork, blackberry, apricot, cherry, quince, walnut, oak, elm, lime, hazel, acacia, palm, maple, juniper, pine, willow, chestnut, and others. The eco-scheme applies from 2023 throughout Romania and is based on the Regulation (EU) 2115/2021 [10]. The eligible area covered by the eco-scheme is 5,750,000 ha of arable land in Romania and belongs to farms of a specified size practicing conventional, semi-intensive or intensive farming [11]. The purpose of the annual payment granted under the eco-scheme is to cover part of the income loss resulting from the additional costs incurred because of meeting the general mandatory and specific conditions mentioned. In addition, in order to be eligible for the eco-scheme, farmers must fully comply with the standards for good agricultural and environmental conditions laid down in the BISS (Basic Income Support for Sustainability) [5] and the cross-compliance rules [5]. The major challenges for mankind nowadays are to implement a sustainable agriculture that provides sufficient food and ecosystem services for both present and future generations [12].

2. Materials and Methods

This research aims to analyse three large crop farms in the Ialomita area, South Muntenia Region, Romania where the following are the existing soil types: in the Mărculești commune area, the dominant soil is calcareous Chernozem, Cernisols class; in the Mihail Kogălniceanu commune area, the dominant soils are represented by Chernozem, Cernisols and Alluviums class, Protisols class; and in Țăndărei commune area, the dominant soil is calcareous Chernozem, within Cernisols class [13]. The sizes of the three farms are approximately 3000 ha (Farm C), 600 ha (Farm B) and 60 ha (Farm A). The area may vary from year to year depending on the areas managed under rent. The objective of this study is the analysis during the pre-

implementation period (i.e., 2019–2022) of the conditions included in the "Environmentally beneficial practices applicable to arable land" eco-scheme and which, in the future, will be the measures that these farmers will have to implement in order to benefit from the subsidy attached to the eco-scheme (for the year 2023, the planned unit amount is of 56.28 euro/ha and the eligible area in Romania is 5,750,000 ha of arable land, belonging to farms from 10.01 ha in size and that are currently practising conventional semi-intensive or intensive farming) [5]. The analysis and the results are based on the Agency for Payments and Interventions in Agriculture's, APIA's, applications for subsidies from 2019 to 2022 [14]. This research aims to highlight the agro-environmental conditions specific to each farm and required to be met by 2023. An analysis is conducted at a farm level on the crop structure (rotation and crop rotation), and the compliance with the eco-scheme for the period under analysis is highlighted to make recommendations for an optimal crop plan under the conditions of the eco-scheme. The analysis at the level of large crop farms is of microeconomic type, but the results can serve as a benchmark for other farms of a similar sizes that would like to access this type of subsidy at the macroeconomic level.

3. Results and Discussions

The large-scale farms analysed (both owned and rented) had the following areas during the 2019–2022 period [14]: the big-sized farm (Farm C)—2956.78 ha in 2019 and decreased in 2022 to 2881.33 ha; the medium-sized farm (Farm B)—608.57 ha in 2019 and an oscillating evolution in the following years, registering 615.50 ha in 2022; the small-sized farm (Farm A), with an area of 30.96 ha and which in 2019 grew rapidly, reaching 64.97 ha in 2022 (Figure 1).

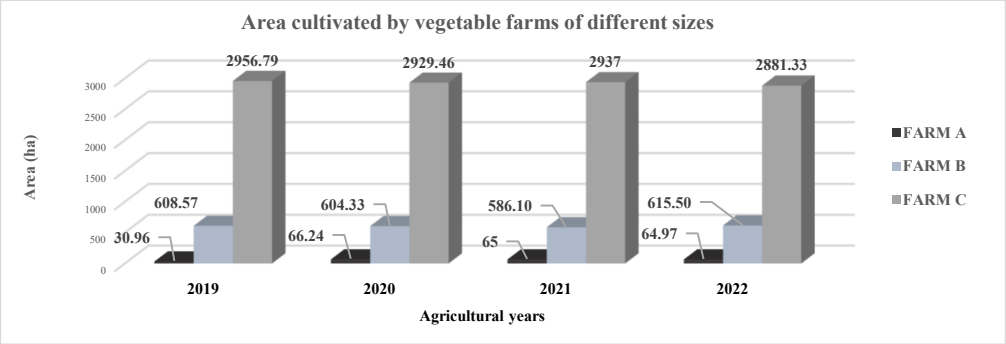

Figure 1. Area dynamics of the three differently sized crop farms studied.

Regardless of the technology applied to this differently sized farms, a rational crop rotation can solve many problems. Even if some crops are apparently less profitable, the advantages and the harvest surplus they can offer to the following crops are superior. The government, through appropriate policy instruments, imposes limits and conditions on farmers, aiming to bring the private optimum (oriented towards microeconomic rationality) to the social optimum (linked to macroeconomic rationality) [15]. Through the obtained results, we identify how open the Romanian farmers are to the new guidelines set for the implementation of new environmental protection policies and what measures can be implemented before they become mandatory [16]. Agroecology evolved as a science [17], providing alternative farming strategies such as emphasizing rotations, vegetables, cover cropping, etc. [18].

3.1. Analysis Regarding Rotation and Crop Rotation System on the 60 ha Farm (Farm A)

On this farm, the land use during the 2019–2022 period is shown in Table 1. We analyse this crop rotation in terms of not only crop rotation, but also the future application of the eco-scheme of environmentally beneficial practices applicable to arable land, with all the mandatory conditions and specific conditions [14].

Table 1. Land use of small-sized farms during the 2019–2022 period (Farm A).

Crop	2019		2020		2021		2022	
	ha	%	ha	%	ha	%	ha	%
Winter wheat	8.69	28.07	37.44	56.52	32.83	50.51	18.85	29.01
Maize	13.77	44.48	16.77	25.32	21.65	33.31	19.93	30.68
Sunflower							17.15	26.40
Fresh vegetables	3	9.69	2.53	3.82	2.17	3.34	3.54	5.45
Alfalfa	5.5	17.76	5.5	8.30	5.5	8.46	2	3.08
Watermelon and melon			2	3.02	2.85	4.38	2	3.08
Pea			2	3.02			1.5	2.31
Total	30.96	100	66.24	100	65	100	64.97	100

In case of winter wheat cultivation (Table 2), at a small-sized crop farm level, it accounted for a considerable share of the total cultivated area. In the 2020–2021 period, winter wheat cultivation accounted for more than 50% of the total agricultural area at a farm level. In 2022, wheat cultivation accounted for 29.01% of the total farm area. Maize crop had a considerable share of 44.48% in 2019, and in 2022, it decreased to 30.68% of the farm area. Sunflower was included in the farm crop rotation in 2022 and had a share of 26.40% of the total farm area. During the 2019–2022 period, alfalfa a low share at the farm level, displaying a decreasing trend from 17.76% in 2019 to 3.08% in 2022. Pea was found in the farm silage in 2020 and 2022, with insignificant shares of 3.02% and 2.31%, respectively. Besides field crops, fresh vegetables (pepper species), watermelon and melon were cultivated on small areas on the farm. In 2022, fresh vegetables accounted for 5.45% of the total farm psace and watermelon accounted for 3.08% of the total farm space.

Table 2. Winter wheat crop rotation on existing plots in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	Area ha	Crop	Area ha	Crop	Area ha	Crop	Area ha
Maize	1	Maize	0.93	Winter wheat	1	Winter wheat	1
Maize	4.34	Maize	4.34	Winter wheat	4	Winter wheat	4.34
				Maize	2.69	Winter wheat	8.81
				Maize	5.12	Winter wheat	4.7

The eco-scheme requirement to include introduction of protein crops the annual crop plan (10% in 2023 and 5% in 2024) aims to enrich the soil in nitrogen, favouring increased production of the next crops included in the set-aside category. Owners of differently sized farms need to take certain recommendations into account to achieve efficient soil management. Thus, the land ploughed in winter should be sown with less demanding crops that can be sown with good results in March, such as oats, triticale (spring varieties), and peas. Sunflower cannot be grown after plants attacked by white rot fungus, such as soybean, beans and rapeseed, after tobacco (attacked by broomrape) or after potatoes and cannot be grown again on the same land for 5–6 years. Soybean cannot be grown after sunflower and rapeseed for the same reason, but neither after other leguminous. Maize treated with thiazine-based herbicides cannot be used as a preceding crop for soybean, beans, sunflower or sugar beet. Very good preceding crops for rapeseed are peas and other leguminous varieties, but these are often distributed to winter wheat and barley. Therefore, for rapeseed, the winter cereals are considered effective pre-fertilizers. Rapeseed cannot be grown after beans, soybean, and sunflower, as *Sclerotinia* is a common disease. For winter cereals, perennial grasses are very good preceding crops. Crop rotation is considered a promising agricultural practice because it enhances key elements of biodiversity, increases

resource efficiency, reduces pests, and stabilizes the production function of the ecosystem over time [19].

On Farm A, maize or winter wheat monoculture is frequently practiced, which is in dissonance with the requirements of agricultural practices as well as the eco-scheme requirements. Winter wheat after winter wheat cultivation (Tables 2 and 3) is a problem that needs to be analysed starting with plant biology, farm crop structure, agro-meteorological and climatic conditions of the specific crop cultivation year and crop technology applied [14]. Even if winter wheat can be grown in monoculture for a large period without observing a noticeable yield decrease, in less favourable years, wheat monoculture leads to considerable yield drops. This yield decrease in wheat crops grown in monoculture is caused by soil sealing, diseases and pest spreading, and the accumulation in the soil of a rhizosphere bacterial flora which, through its vital products, is detrimental to the growth and proper functioning of the wheat roots. The influence of the preceding crop on winter wheat production is decisive from one year to another.

Table 3. Maize crop rotation per existing plot in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
		Winter wheat	20	Winter wheat	12	Maize	19.93

The best preceding species for winter wheat are peas, beans, rapeseed, clover, mustard, chickpea, and silage maize. The best preceding crops for maize are annual grain and fodder legumes, cereals and sunflower. It is obvious that wheat production increases in thr wheat–maize rotation compared to monoculture, and this rotation is the most extensive in Romania and is of economic importance. Winter wheat production in the winter wheat–maize rotation is much lower than the production obtained in the long-time rotations. To comply with the eco-scheme codes, clover should be introduced into the rotation, as it improves soil fertility and increases wheat production compared to a two-year rotation (winter wheat–maize) (Table 3). In a three-year rotation, peas could be used as a soil improvement plant, which can increase winter wheat production. Over the years, winter wheat production within winter wheat–maize rotation is clearly decreasing, despite the annual use of chemical fertilizers, and one of the eco-scheme conditions emphasizes crop diversification. Compared to long-term rotations, in the winter wheat–maize rotation, crop phytosanitary condition is obviously worse. In addition, to comply with the conditions of the eco-scheme, it is recommended to introduce technical plants and some grain legumes on the fallow land.

The best preceding crops for sunflower cultivation are maize [14], winter cereals and peas (Table 4). When cultivating sunflower, it is recommended to grow it again on the same land only after four–five years. In this case, the rotation recommendations are maize and winter wheat as preceding crops for sunflower. The restrictions on sunflower cultivation are given by the regrow time on the same plot, which are 5–6 years, and by the maximum share of 18–20% of the farm area, which, if not complied with, can reduce the average yield to no more than 1000 kg/ha.

Vegetable crops (Table 5) are grown on small areas on small-sized crop farms, and the rotation aims to use the soil intended for this type of crop. These crops are often grown on soils that were not cultivated in the previous year [14].

Alfalfa (Table 6) can be present on the field for several years (3–5 years). In 2022, the farm cultivated alfalfa after winter wheat and on the uncultivated field [14]. Alfalfa is also a good preceding crop for most crop species and is mentioned in the eco-scheme application conditions.

Table 4. Sunflower crop rotation on existing plots in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
		Winter wheat	12	Maize	12	Sunflower	12
				Winter wheat	7.19	Sunflower	4.73
						Sunflower	0.42

Table 5. Fresh vegetable crop rotation on existing plots in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
		Watermelon and melon	2			Fresh annual vegetables	1.47
						Fresh annual vegetables	2.07

Table 6. Alfalfa crop rotation on existing plots in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
				Winter wheat		Alfalfa	1.23
						Alfalfa	0.77

The best preceding crops for peas are spring cereals and maize. Peas for grain are a very valuable leguminous plant both nutritionally (feed, food) and agronomically (nitrogen fixing). In the farm, grain peas have grain maize as their main crop. Peas for grain is an agricultural crop that is sown in early spring.

Peas (Table 7) can be grown after crops that are harvested earlier and allow early tillage, i.e., cereals and some feed crops.

Table 7. Rotation of grain pea crop on existing plots in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
		Maize	1.5	Maize	1.5	Pea	1.5

The melon crop (Table 8) has as preceding crops the fresh annual vegetables (*Capsicum* species). The best preceding crops for melon cultivation are straw cereals, maize, perennial legumes (clover, alfalfa), which leave the soil weed free and well structured. Melon crop can be grown on the same land area on which it was cultivated after 3–4 years.

Table 8. Watermelon and melon crop rotation on existing plots in 2022 (Farm A).

Agricultural Year							
2019		2020		2021		2022	
Crop	Area ha	Crop	Area ha	Crop	Area ha	Crop	Area ha
Fresh annual vegetables	2.3	Fresh annual vegetables	0.3	Fresh annual vegetables	2.17	Watermelon and melon	2

3.2. Analysis Regarding Rotation and Crop Rotation System on the 600 ha Farm (Farm B)

In Farm B [14], the largest area is cultivated with maize. For example, in 2022, 302.50 ha were cultivated with maize, which represents 49.15% of the whole farm. After maize cultivation, in 2022, on 236.40 ha, soybean was cultivated, representing a considerable share of 38.41% (Table 9).

Table 9. Land use of medium-sized arable land farm during 2019–2022 period (Farm B).

Crop	2019		2020		2021		2022	
	ha	%	ha	%	ha	%	ha	%
Winter wheat	203.41	33.42	156.69	25.93	86.00	14.67	51.60	8.38
Rapeseed	154.09	25.32	125.31	20.74				
Maize	214.94	35.32	250.60	41.47	203.00	34.64	302.50	49.15
Alfalfa	20.37	3.35	20.37	3.37	22.10	3.77	25.00	4.06
Soybean	15.76	2.59			156.50	26.70	236.40	38.41
Spring oats			6.11	1.01	8.20	1.40		
Winter barley			45.25	7.49	110.30	18.82		
Total	608.57	100	604.33	100	586.10	100	615.50	100

Winter wheat was grown on 51.60 ha, which represents 8.38% of the area cultivated on the farm in 2022, and alfalfa was cultivated on 25 ha, i.e., 4.06% of the total farm area. In 2022, no rapeseed, oat, and barley crops were cultivated.

Concerning rotation in the winter wheat crop (Table 10) in 2022 [14], winter wheat was frequently grown on the same land after other cereals, like barley and oats, and from this point of view, special attention must be paid to the control of weeds, diseases and pests, which are common for cereals. Grain maize was also a preceding crop during the period under review.

Table 10. Wheat crop rotation on existing plots in 2022 (Farm B).

Agricultural Year							
2019		2020		2021		2022	
Crop	Area ha	Crop	Area ha	Crop	Area ha	Crop	Area ha
Maize	17.50	Maize	17.50	Winter barley	18.10	Winter wheat	4.6
Rapeseed	4.23	Maize	18.59	Winter barley	18	Winter wheat	20
Maize	2.34	Winter wheat	2.34	Winter barley	2	Winter wheat	2
Maize	5.18	Winter wheat	5.18	Maize	4	Winter wheat	4
Winter wheat	7.84	Maize	7.84	Winter barley	8	Winter wheat	19
		Oats	2	Spring oats	2	Winter wheat	2

Concerning maize crop (Table 11), this can be regrown after winter wheat, oat, maize and soybean species. Maize monoculture is noted on a considerable area of 96.50 ha. As shown in the small-sized farm (Farm A), the cultivation of winter wheat in monoculture is suitable for two or three consecutive years while applying fertilizers and tilling the soil in

the best conditions. The cultivation of winter wheat after winter wheat is recommended during dry autumns, when, after a late harvesting, the soil bed preparation cannot be achieved properly, and sowing cannot be performed in due time. In this case, wheat yields in monoculture are obviously higher than yields obtained in rotation with late-harvesting plants. However, fertilizers can only partially compensate for the positive effect of the preceding plant in wheat monoculture, so the condition of continuous diversification in the eco-scheme obviously marks this aspect, forcing farmers to respect it. After two or three years of monoculture, wheat yield decreases, regardless of fertilizer application. Even under irrigated conditions, monoculture is excluded, since after the wheat harvest, a fodder or grain crop must be sown immediately, which ensures a second harvest.

Table 11. Maize crop rotation per existing plot in 2022 (Farm B).

Agricultural Year							
2019		**2020**		**2021**		**2022**	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
						Maize	13.50
Winter wheat	59.91	Rapeseed	48.91	Winter wheat	49	Maize	60
		Winter wheat	97.39	Maize	102	Maize	96.50
Winter wheat	0.51	Oats	0.51	Spring oats	1	Maize	0.50
Maize	45.25	Winter barley	45.25	Soybean	60	Maize	68
						Maize	64

Two-year winter wheat–maize rotation is not a beneficial solution since maize, which under irrigated conditions is represented by the most productive forms (late or semi-late), does not provide adequate conditions for sowing winter wheat at the optimal time. In order to comply with the eco-scheme conditions, when farmers make up the crop rotation, they must take into account the fact that winter wheat must have as a preceding crop a species which is harvested before maize and which improves soil fertility. We recommend soybean, which is mentioned in the eco-scheme as a nitrogen-fixing plant, but sunflower is also suitable. Additionally, under irrigated conditions, the preceding crop for winter wheat is as important as it is on non-irrigated land in the regular crop to obtain high yields.

In 2022, soybean crop had maize as a preceding crop. Soybean (Table 12) is recommended by the eco-scheme to be cultivated as a protein, nitrogen-fixing plant. Soybean crop can be grown on the same land after three to six years, because is sensitive to weeds. It is recommended to take into account the weed species which exist on the land which is cultivated with this species, including the preceding crops. The benefits of intensive soybean rotation are undeniable given the similarity to maize in terms of nutrient requirements.

Table 12. Soybean crop rotation on existing plots in 2022 (Farm B).

Agricultural Year							
2019		**2020**		**2021**		**2022**	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
Winter wheat	50	Maize	50	Maize	20	Soybean	81.40
		Rapeseed	54.65	Maize	55	Soybean	155

In 2022, the alfalfa crop (Table 13) was cultivated on 25 ha, out of which 23 ha were established in 2022 with barley as the parent crop [14]. Alfalfa can be grown on the same land after a period which is equal to its growing time, and after, in rotation, farmers who apply the eco-scheme can grow spring-sown annuals such as maize.

Table 13. Alfalfa crop rotation on existing plots in 2022 (Farm B).

Agricultural Year							
2019		2020		2021		2022	
Crop	Area ha	Crop	Area ha	Crop	Area ha	Crop	Area ha
Rapeseed	16.01	Maize	16.01	Winter barley	16	Alfalfa	23
		Alfalfa	1.51	Alfalfa	2	Alfalfa	2

3.3. Analysis Regarding Rotation and Crop Rotation System on the 3000 ha Farm (Farm C)

In this farm (Table 14), there is a greater diversity of crops and a more even distribution in terms of the occupied area. In 2022, maize crop occupied the largest area of 748.78 ha, which represents 25.99% of the total farm area.

Table 14. Land use of big-sized crop farms during 2019–2022 period (Farm C).

Crop	2019		2020		2021		2022	
	ha	%	ha	%	ha	%	ha	%
Winter wheat	783.75	26.60	713.66	24.36	716.89	24.41	523.51	18.17
Sunflower	267.07	9.06	501.27	17.11	428.76	14.60	497.86	17.28
Winter barley	240.57	8.16	207.89	7.10	214.79	7.31	253.22	8.79
Maize	486.61	16.51	564.06	19.25	754.11	25.68	748.78	25.99
Rapeseed	476.899	16.18	447.84	15.29	254.32	8.66	192.92	6.70
Soybean	677.23	22.98	470.42	16.06	536.75	18.28	641.59	22.27
Fresh vegetables	4.71	0.16						
Flower and ornamental plants	3.14	0.11	1.12	0.04	0.85	0.03		
Potatoes	4.74	0.16	13.2	0.45	14.53	0.49	23.45	0.81
Sweet potatoes	2	0.07	10	0.34	16	0.54		
Total	2946.72	100	2929.46	100	2937.00	100	2881.33	100

With a considerable share (22.77%), soybean crop stands out, occupying an area of 641.59 ha in 2022, followed by wheat with 523.51 ha (18.17%) and sunflower with 497.86 ha (17.28%). Smaller areas were cultivated with winter barley (253.22 ha), which represents 8.79% of the farm area, rapeseed (192.92 ha) representing 6.70% of the farm area and potatoes (23.45 ha) representing 0.81% of the farm area. In 2022, the farm did not grow any more vegetables, ornamental flowers, or other potato crops (Table 14).

At the 2022 level, the winter wheat crop had the following preceding crops: rapeseed, sunflower, maize, barley and uncultivated field (Table S1).

In 2022, maize had soybean, winter wheat, rapeseed and maize as its preceding crops. The largest areas under maize were cultivated with soybean as a preceding crop, but it should be noted that maize monoculture was also practiced at a farm level on an area of 111.51 ha (Table S2).

The inclusion of sunflower in the plot is beneficial for increasing biodiversity and soil fertility, reducing the spread of weeds, diseases, and pests. Regarding the sunflower crop, in 2022, it can be seen that it had winter wheat, barley, rapeseed and uncultivated field as its preceding crops (Table S3). Frequently, sunflower is cultivated after winter wheat or barley. It can also be seen that on a 1.41 ha, the rapeseed–sunflower rotation was practiced, but this type of rotation is not repeated because the two species have common pathogens. Farmers applying for the eco-scheme should bear in mind that the sunflower crop is very demanding in terms of the location in the set-aside category and regrowing on the same field within the set-aside category.

The best preceding crop for rapeseed is the leguminous and grassy crops that could be harvested early. At the 2022 level, the preceding crop was winter wheat. Regarding the eco-scheme requirements, the best preceding species for rapeseed are the crops that are early harvested, and so the necessary period for land preparation and sowing is good; also,

there is sufficient time for the soil to accumulate the water needed for sprouting (cereals, peas, extra early and early potatoes, clover). Farmers should bear in mind that rapeseed should not be grown in monoculture or after crops such as sunflower, soybean, beans, and chickpea that are attacked by white rot (Table S4).

The best preceding crops for winter barley are peas, beans, rapeseed, clover, potatoes, oats, soybean and silage corn. Barley had sunflower as a preceding crop. When growing barley, farmers, should bear in mind that it can be grown after different preceding plants and its place in the rotation should be determined according to its biological characteristics and the purpose for which it is grown (Table 15).

Table 15. Barley crop rotation on existing plots in 2022 (Farm C).

Agricultural Year							
2019		**2020**		**2021**		**2022**	
Crop	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**	**Crop**	**Area ha**
Winter wheat	172.13	Winter wheat	142.84	Sunflower	193.47	Winter barley	193.47
				Sunflower	59.75	Winter barley	59.75

The best preceding crops for soybean are winter cereals, spring peas and maize. In soybean, it is noted that at the 2022 level, corn, winter wheat and soybeans were the most important preceding crops. It is noted that on an area of 13.41 ha, soybean monoculture was practiced, but this is not recommended due to pathogens, pests, and weeds (Table S5).

In 2022, the potato crop was established on an area that was uncultivated the previous year, which complies with the conditions of the eco-scheme. The potatoe monoculture is not recommended, only a rotation of two (if no nematode attack has been reported) to four years is recommended. It should also be pointed out that potatoes cannot be grown after other Solanaceous crops, nor after sugar beet, and the best preceding species are grasses, cereals, clover, alfalfa, annual legumes, maize, vetch, flax, sunflower, roots or bulbous plants, and its introduction into the soil is also important to respect the eco-scheme conditions.

3.4. Discussions on the Implementation of Eco-Scheme Conditions at a Farm Level

When applying the requirement of the "Environmentally beneficial practices on arable land" eco-scheme for conservation farming on 50% of the farm (no tillage–strip tillage–minimum tillage), tillage is a key element in the transition to minimum tillage or even its exclusion. Conservative agriculture is based on the minimum amount of work applied to the soil, an optimal rotation of crops and the incorporation of plant residues for soil coverage; it is recommended for the sustainable production of crops with an emphasis on resource efficiency and cost reduction [20–25]. Thus, the need for crop diversification is urgent in this type of farming, as plants take over some of the roles of technological tillage and improve the soil and therefore need to be properly chosen. In conservation farming, the rules are as follows [26]: ensure as many crops as possible (minimum four crops) so that each one has a necessary "task" to perform; achieve maximum soil coverage and include successive crops based on the fundamental principles of conservation farming (i.e., soil protection and plant cover, and soils with a greater diversity of crops, including successive crops, taking account of rational fertilization and the maximum cover throughout the year). Another rule is to focus on the efficient use of nutrients in the soil, considering that each species consumes different quantities of elements, which can contribute to the accumulation of some in the soil and the release of others, and the choice of crops should be made taking this into account [27].

These recommendations are important in the establishment of the crop rotation systems, but it should be mentioned that each agricultural land has its own particularities and needs. The medium and big-sized crop farms considered in this study practice conservation farming, while the small-sized crop farm does not practice conservation farming.

Tillage is a system of sustainable crop management leading to the protection of soil, water, air and biodiversity [28–30].

Between the nitrogen-fixing protein crops required by the eco-scheme to be introduced into the soil, the three crop farms chose to grow soybean and peas.

Thus, the analysis highlighted that the conditions of the "Environmentally Beneficial Practices applicable on arable land" eco-scheme were respected by the three differently sized crop farms in the period prior to its introduction in the National Strategic Plan of Romania. The description is presented in Table 16.

Table 16. Proposal on how to fulfil the conditions required by the eco-scheme environmentally beneficial practices on arable land.

Condition Type	Condition in the Eco-Scheme	Farm A	Farm B	Farm C
General Mandatory conditions	Existence of non-productive elements on the total arable area of the farm (5% of the annual area).	No		
	Establishment of protein crops: soybean, peas, field peas, asparagus, clover, field beans, chickpea, lupine, lentils, alfalfa, peanuts, mixtures of legumes and perennial grasses.	Yes (peas)	Yes (alfalfa, soybean)	Yes (soybean)
	Ground cover on 85% of the area throughout the agricultural year (period requested and analysed 15 June–15 October 2022).	Yes Only 68.69% of the area was covered with maize, sunflower, vegetables, melons, alfalfa, and 29.01% of the area was covered with stubble left after wheat harvesting.	Yes 91.62% of the area was covered with maize, soybean, alfalfa and 8.38% of the area was covered with stubble left after wheat harvesting.	Yes 66.35% of the surface was covered with. maize, sunflower, soybean, potato, vegetables and 26.96% of the area was covered with stubble left after wheat and barley harvesting.
Specific conditions (one, of farmer's choice)	Crop diversification (May–September): minimum 3 crops, out of which main crop ≤70% and two main crops ≤85%. Analysis of the 2022 agricultural year.	Yes Minimum 3 crops: maize, sunflower and alfalfa. Main crop: maize 30.68% Two main crops: maize and sunflower: 57.08%.	Yes (partly) Minimum 3 crops: maize, soybean, and alfalfa. Main crop: maize, 49.15% Two main crops: maize and soybean, 87.56%. (Recommendation: 2.56% reduction)	Yes Minimum 3 crops: maize, sunflower and soybean. Main crop: maize 25.99% Two main crops: maize and soybean: 48.26%.
	Conservation farming: no tillage, strip tillage or no minimum strip tillage on 50% of the total arable area of the farm	No The size of the plots is small, hence the high degree of fragmentation at farm level. Not suitable for modern, conservative, no-tillage, strip-tillage or minimum-tillage practices (investment is very high and the farmer does not have sufficient income for implementation).	Yes Large surface area. Medium to large plots. Existing farm facilities (technical equipment) allow the use of conservation-tillage, no-tillage, strip-tillage or minimum-tillage technologies.	
	Planting 2 trees per hectare. Tree species: apple, peach, plum, blackberry, currant, cherry, hickory, walnut, oak, elm, lime, hazel, acacia, birch, maple, sycamore, pine, savoury, chestnut, and other species.	No		

3.5. Optimum Cropping Plan Recommendations for the Three Large Crop Farms

The actions taken by farmers should, however, be in line with the main assumptions of the concept known as Intensification of Sustainable Agriculture, which indicates the effective use of production means [31]. For the three differently sized crop farms, the optimal cropping plan, based on the agro-technical principles of soil management and the requirements of the eco-scheme of environmentally beneficial practices applicable to arable land, are described in Table 17.

Table 17. Optimum cropping plan.

Farm A			Farm B			Farm C		
Type of Culture	**Surface**		**Type of Culture**	**Surface**		**Type of Culture**	**Surface**	
	%	**ha**		**%**	**ha**		**%**	**ha**
Non-productive elements (including uncultivated land)	5%	3.25	Non-productive elements (including uncultivated land)	5%	30.78	Non-productive elements (including uncultivated land)	5%	144.07
Leguminous crops (perennial crops—alfalfa and annual crops—peas)	10%	6.50	Leguminous crops, of which:	40%	246.20	Leguminous crops (annual crops—soybean)	25%	720.33
			Perennial crops (alfalfa)	5%;	30.78			
			Annual crops (soybean)	35%	215.42			
Cereal crops (maximum)	25%	16.24	Cereal crops	15%	92.33	Cereal crops (maximum)	25%	720.33
Maize crop	30%	19.49	Maize crop	30%	184.65	Maize crop	25%	720.33
Sunflower crop	20%	12.99	Oilseed crops (sunflower, rapeseed)	10%	61.55	Oilseed crops (sunflower, rapeseed)	18%	518.64
Watermelon crop	5%	3.25				Potato crop	2%	57.63
Vegetables crop	5%	3.25						

Agricultural management typically applies several strategies, and crop rotations are one of the most important strategies [32–34]. It is common for small-sized farms to cultivate the same crop continuously because of a lack of expertise. The farming system considerably affects chemical soil properties [35], and the recommendations consider the size of the farm, the requirements of the eco-scheme, and the land use at farm level.

For Farm A, it is recommended to comply with the eco-scheme conditions (5% non-productive elements, including uncultivated land, i.e., 3.25 ha and 10% leguminous crops, i.e., 6.50 ha) and to achieve crop diversification (maximum 25% of cereals, i.e., 16.25 ha, 30% of the area should be cultivated with maize, i.e., 19.49 ha, 20% of the area should be cultivated with sunflower, i.e., 12.99 ha, 5% of the area should be cultivated with watermelon, i.e., 3.25 ha and 5%, i.e., another 3.25 ha with vegetables) (Figure 2).

For Farm B, it is recommended to comply with the eco-scheme conditions (5% non-productive elements, including uncultivated land, i.e., 30.78 ha and 40% leguminous crops, i.e., 246.20 ha, of which 5% perennial crops, i.e., alfalfa, 30.78 ha and 35% annual crops, i.e., soybean, 215.42 ha) and to achieve crop diversification (maximum 15% cereals, i.e., 92.33 ha, 30% of the area with maize, i.e., 184.65 ha, 10% of the area with oilseed crops, i.e., sunflower and/or rapeseed, i.e., 61.55 ha) (Figure 3).

Farm C, it is recommended to comply with the eco-scheme conditions (5% non-productive elements, including uncultivated land, i.e., 144.07 ha and 40% annual leguminous crops (soybean), i.e., 720.33 ha, and to achieve crop diversification (maximum 25% cereals, i.e., 720.33 ha, 25% of the area is used to grow maize, i.e., 720.33 ha, 18% of the area is used to grow oilseed crops, i.e., sunflower and/or rapeseed, i.e., 518.64 ha and 2% of the area is used to grow potatoes, i.e., 57.63 ha (Figure 4).

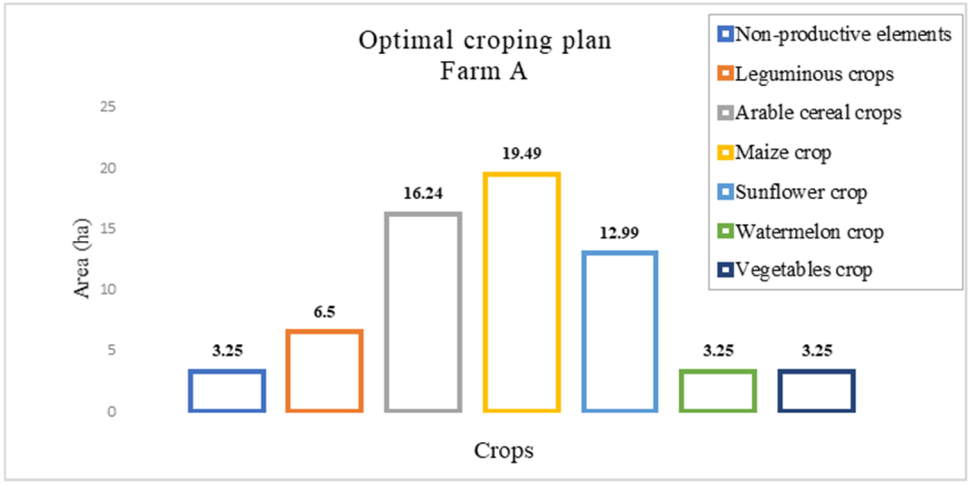

Figure 2. Farm A (60 ha).

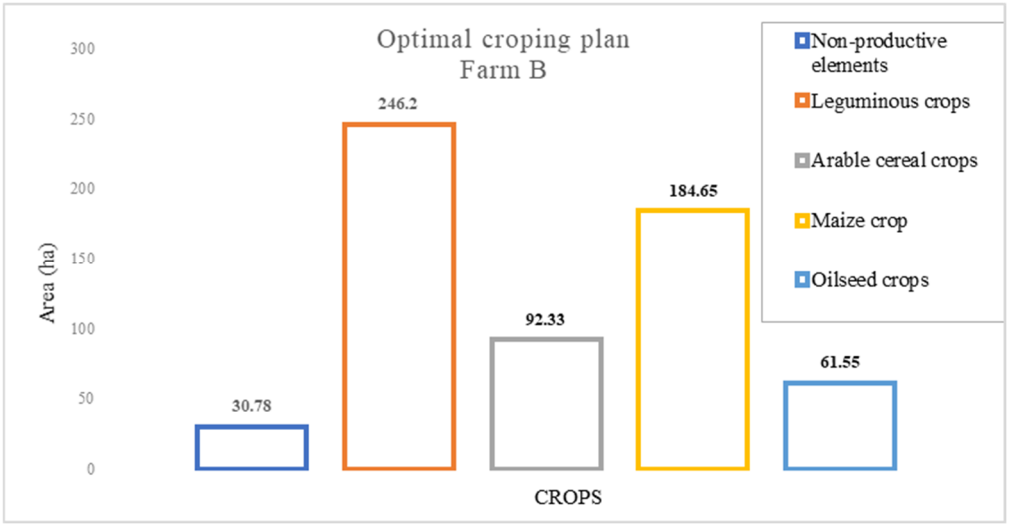

Figure 3. Farm B (600 ha).

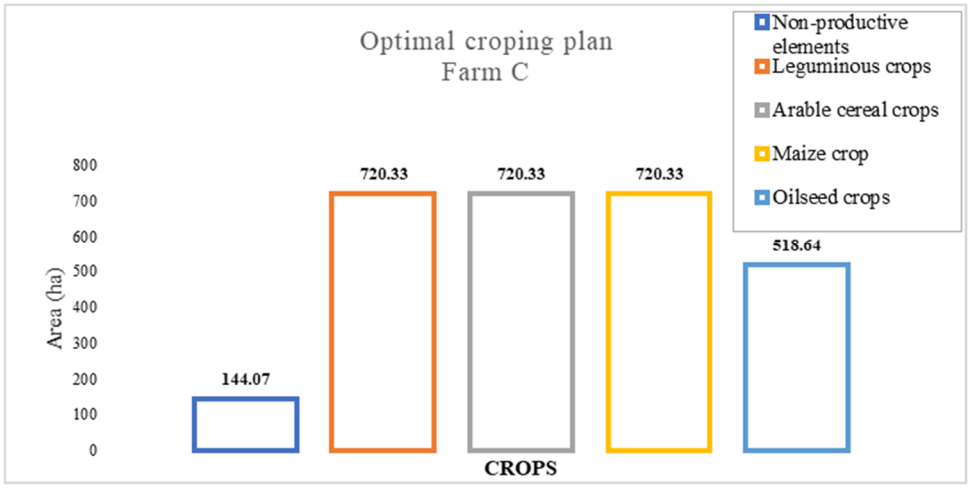

Figure 4. Farm C (3000 ha).

In order to meet the requirements of the eco-scheme, we recommend farmers to introduce green crops that aim to keep the land covered during the period mentioned in the eco-scheme.

Cover crops can influence water content, pore size distribution and water infiltration with a direct influence on soil chemistry [36,37]. Crop rotation can create a good soil environment, increase soil moisture and promote the reproduction and growth of microorganisms. Microorganisms act as mediators to catalyse the enzyme reaction process, thus increasing enzyme activity, increasing soil fertility, and improving the ability of crops to withstand extreme weather [38].

4. Conclusions

In order to maintain their agricultural and economic performance in the context of climate change and legislative updates in this regard, farms are obliged to introduce the measures contained in the National Strategic Plan 2023–2027, as well as the conditions in the eco-scheme of beneficial practices for the environment applicable on arable land. For farms with similar sizes that want to apply the eco-scheme in the future, the recommendations are as follows:

- Farms under 100 ha (Farm A) which do not apply modern technologies and have fragmented surfaces must have both uncultivated surfaces and nitrogen-fixing crops, but also practice crop diversification.
- Farms of over 100 ha (Farms B and C) must implement the eco-scheme by including non-productive areas on 5% of the surface. As the rest of the conditions are already met, these farms have the ability to practice a conservative type of agriculture and use crop diversification, including growing nitrogen-fixing plants.

To easily fulfil the conditions of the eco-scheme, green crops are an advantage for the optimal cropping plans of the farms, the benefits being both for the soil and for obtaining subsidies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy13082086/s1, Table S1: Winter wheat crop rotation on existing plots in 2022 (Farm C); Table S2: Maize crop rotation per existing plot in 2022 (Farm C); Table S3: Sunflower crop rotation on existing plots in 2022 (Farm C); Table S4: Rotation of rapeseed on existing plots in 2022 (Farm C); Table S5: Soybean crop rotation on existing plots in 2022 (Farm C).

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