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Assessment of sustainability of agro-ecosystems in Bulgaria

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Abstract

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Ecosystem approach has been widely incorporated in management and evaluation of sustainability levels. Despite enormous progress in this new evolving area, still there is no consensus on how to assess the sustainability of agro-ecosystems due to diverse understandings, approaches, methods, employed data, etc. In Bulgaria there are no comprehensive studies on integral and socio-economic and ecological sustainability of agro-ecosystems of different type. This paper makes a first attempt to assess sustainability agro-ecosystems in Bulgaria. Initially, a holistic framework for assessing integral, economic, social and ecological sustainability of agro-ecosystems including 17 principles, 35 criteria, and 46 indicators and reference values is suggested. After that overall and aspects sustainability of 7 generic and 10 specific agro-ecosystems in Bulgaria is assessed. Estimates are based on first-hand information collected by the managers of typical farms operating in different agro-ecosystems in 4 geographical regions of the country. The study has found out that there is a substantial variation in the level of integral and aspects sustainability of agro-ecosystems of different type as well as in sustainability contribution of various sub-sectors of agriculture and farms of different juridical type and size as individual indicators with the highest and lowest values showing (critical) factors enhancing and deterring sustainability. Results on integral agrarian sustainability level of this study based on the micro agro-ecosystem (farm) data are similar to the previous assessment based on the aggregate sectoral (statistical, etc.) data.

Keywords: agro-ecosystems**;** sustainability; economic; social; ecological; Bulgaria

Introduction

The issue of assessment of sustainability of agricultural systems of various type is among the most topical in last decades (FAO, 2013; Fuentes, 2004; Hayati et. al., 2010; Lopez-Ridauira et. al. 2002; Sauvenier et al., 2005; Rezear et al., 2018; Todorova & Treziyska, 2018; VanLoon et al. 2005; Zvetkova and Sarov, 2018). In recent years an "ecosystem approach" has been increasingly incorporated in the management and evaluation of sustainability levels (Belcher, 1999; Bohlen and House, 2009; MEA, 2005; De Oliveira, 2018; Sidle et al., 2013). Despite enormous progress in the theory and practice of this new evolving area, still there is no consensus on how to assess the sustainability of agro-ecosystems due to diverse understandings, approaches, methods, employed data, etc. In Bulgaria comprehensive sustainability assessments are mostly on sectoral (Bachev et al., 2017) or farm (Bachev, 2017; Bachev & Treziev, 2017) levels while there is practically no in-depth study on sustainability agro-ecosystems. The goal of this paper is to assess the sustainability level of agro-ecosystems of different type in Bulgaria.

Materials and Methods

For assessing sustainability level of agro-ecosystems in Bulgaria a holistic hierarchical system is elaborated including 17 principles, 35 criteria, and 46 indicators and

Table 1. System of principles, criteria, indicators, and reference values for assessing sustainability level of agro-ecosystems in Bulgaria

Principles	Criteria	Indicators	Reference values
Economics aspect			
Financial stability	Reducing dependence on subsidies	Share of direct payments in Gross Value Added	Experts estimate/ Trend
	Sufficient liquidity	Ratio of overall liquidity	Experts estimate/ Trend
		Ratio of quick liquidity	Experts estimate/Trend
	Minimizing dependence on external capital	Share of owned in total capital	Experts estimate/ Average for the sector
Economic effectiveness	Positive or high profitability	Cost – effectiveness	Experts estimate/ Average for the sector
		Profitability of capital	Experts estimate/ Average for the sector
	Maximize or increase labour productivity	Labour productivity	Experts estimate/ Average for the sector
	Maximize or increase land productivity	Productivity of land	Experts estimate/ Average for the sector
	Maximize or increase livestock productivity	Livestock productivity	Experts estimate/ Average for the sector
Competitiveness	Support or increase of marketed output	Share of marketed output	Experts estimate/Trend
	Support or increase of sales	Sales growth in the last 3 years	Experts estimate/ Trend
Adaptability to economic environment	Sufficient adaptability to market environment	Ratio of gross income to fixed costs	Experts estimate/ Trend
	High investment activity	Investment growth	Average for the sector/ Trend
Social aspect			
Welfare of employed in agriculture	Equality of income with other sectors	Ratio of farm income to the average income in the region	Experts estimate/ Trend
	Fair distribution of income in agriculture	Ratio of payment of hired labour in the farm to average income in the region	Average for the sector/ Trend
	Sufficient satisfaction from farm activity	Degree of satisfaction from farm activity	Farmers assessment
	Satisfactory working conditions	Correspondence to official norms	Official norms
Conservation of farming	Preservation of the number of family farms	Existence of a heir ready to take over the farm	Experts estimate/ Trend
		Number of family workers	Experts estimate/Trend
		Age of the manager	Farmers assessment/Trend
	Increasing the knowledge and skills	Level of participation in the training programs	Experts estimate/ Trend
		Level of education of the manager	Experts estimate/ Trend
	Maintaining and increasing of agrarian education	Number of employed with special agricultural education	Experts estimate/ Trend
Gender equality	Equality in men-women relations	Degree of participation of women in farm management	Half/Trend
Social capital	Participation in professional associations and initiatives	Number of participations in professional associations and initiatives	Experts estimate
		Level of hired labour membership in labour unions	Experts estimate/ Trend
	Participation in public management	Public position	Experts estimate/ Trend
	Contribution to the development of regions and communities	Participation in local initiatives	Experts estimate/ Trend

Table 1. Continued

Principles	Criteria	Indicators	Reference values
Adaptability to the social environment	Sufficient ability to respond to the ceasing farming activity and the demographic crisis	Vacant job positions in the farms to the total number of employed	Experts estimate/ Trend
Ecological aspect			
Air quality	Maintaining and improving air quality	Growth of carbon emissions for the past three years	Trend
Land quality	Minimizing soil losses	Soil erosion index	Scientific norm/ Trend
	Preservation and improvement of soil fertility	Amount of nitrogen fertilization	Scientific norm/ Average for the sector
		Amount of potassium fertilization	Scientific norm/ Average for the sector
		Amount of phosphorus fertilization	Scientific norm/ Average for the sector
	Maintaining a balanced land use structure	Share of arable land (without fallow) in total agricultural areas	Scientific norm/ Average for the sector
	Preservation of landscape features	Amount of area covering the requirements for "green" direct payments through maintaining landscape elements	Experts estimate/ Trend
Water quality	Maintaining and improving water quality	Index of groundwater pollution	Scientific norm/ Average for the sector
Effective energy consumption	Minimizing the use of conventional energy	Fuel consumption per unit area	Experts estimate/ Average for the sector
		Cost of conventional electric energy per unit of gross output	Trend/ Average for the sector
Biodiversity	Maintaining or enhancing natural habitats	Change in the number of habitats	Trend/ Average for the sector
		Share of agricultural land in NATURA 2000 and other protected areas	Planed target Trend/
	Preserving and improving the biodiversity	Number of cultivated plant species	Trend/ Average for the sector
Animal welfare	Compliance with the principles of animal welfare	Level of compliance with the principles of animal welfare	Official norms
Implementation of organic production	Increasing the organic production	Share of areas under conversion or certified for organic production	Experts estimate/ Trend
Adaptability to the environment	Sufficient adaptability to climate change	Variation in the yield of main crops	Average for the sector/ Trend
		Death rate in livestock farms	Average for the sector/ Trend

Source: authors

reference values (Table 1). It adapts well-known SAFE approach (Sauvenier et al., 2005) and identifies appropriate principles, criteria, indicators, and reference values for contemporary conditions of agro-ecosystems in Bulgaria.

In Bulgaria, like in most countries, there are no official data for calculating socio-economic and (some parts of) ecological indicators at agro-ecosystem level. In order to assess the level of sustainability of agro-ecosystems we carried in-depth interviews with the managers of 80 farms of different types and agro-ecological locations in 4 major regions of Bulgaria in 2017. Agro-ecosystems are ecosystems associated with farming activity and the individual farm is the first level for governing of agrarian sustainability (Bachev, 2018). Following criteria were used for the selection of areas for the farm survey (Fig. 1): major administrative and geographic regions (North-Central, South-Eastern, South-Central and South-Western); generic and specific type of agro-ecosystems in the country (mountainous, plain-mountainous, plain, riparian (Struma river, Maritza river, Yantra river), Southern Black Sea, mountainous area with natural constraints, non-mountainous area with natural constraints, protected areas and reserves, Western Thracian Plain, Middle Danube Plain, Dupnitsa and Sandansko-Petrich Valley, Sredna Gora Mountains and Western Rila

Mountains). "Typical" for different agro-ecosystems farms were selected with the assistance of the main associations of farmers, state agencies, processing, bio-certification and service organizations, and local government.

The interviews included questions related to primary information for calculating economic, social and ecological indicators for sustainability at agro-ecosystem level. Estimated quantitative and qualitative levels for each indicator were further transformed into a unitless Index of sustainability (ISi). After than the integral Index for a particular criterion (SI(c)), principle (SI(p)), and aspect of sustainability (SI(a)), and the integral sustainability index (SI(o)) for each farm is calculated as an arithmetic average applying equal weight for every indicator in a particular criterion, of each criterion in a particular principle, and each principle in every aspect of sustainability. The composite sustainability index of a particular agri-ecosystem is an arithmetic average of the indices of relevant farms belonging to that agro-ecosystem. For assessing sustainability level of agro-ecosystems the following scale for Index range is used: 0.85-1 for a high level; 0.50-0.84 for a good level; 0.25-0.49 for a satisfactory level; 0.12-0.24 for unsatisfactory level; and 0-0.11 for non-sustainable.

Results and Discussion

There is a considerable differentiation of the level of integral and aspect sustainability in agricultural ecosystems of different generic types (Fig. 2). The highest integral sustainability has the agriculture in the plane regions (0.63) having also the highest economic sustainability, and the agro-ecosystems in protected zones and territories (0.74). On the other hand, the integral sustainability in mountain regions with natural restrictions is the lowest (0.56). These ecosystems' type has also the lowest (and close to the limits of satisfactory) levels for social sustainability, and the ecosystems in non-mountain regions with natural restrictions (0.52). Nevertheless, the ecological sustainability of agro-ecosystems in mountain areas with natural restrictions is relatively high (0.58).

The integral sustainability of mountain agro-ecosystems is on a medium level (0.58), but while its economic

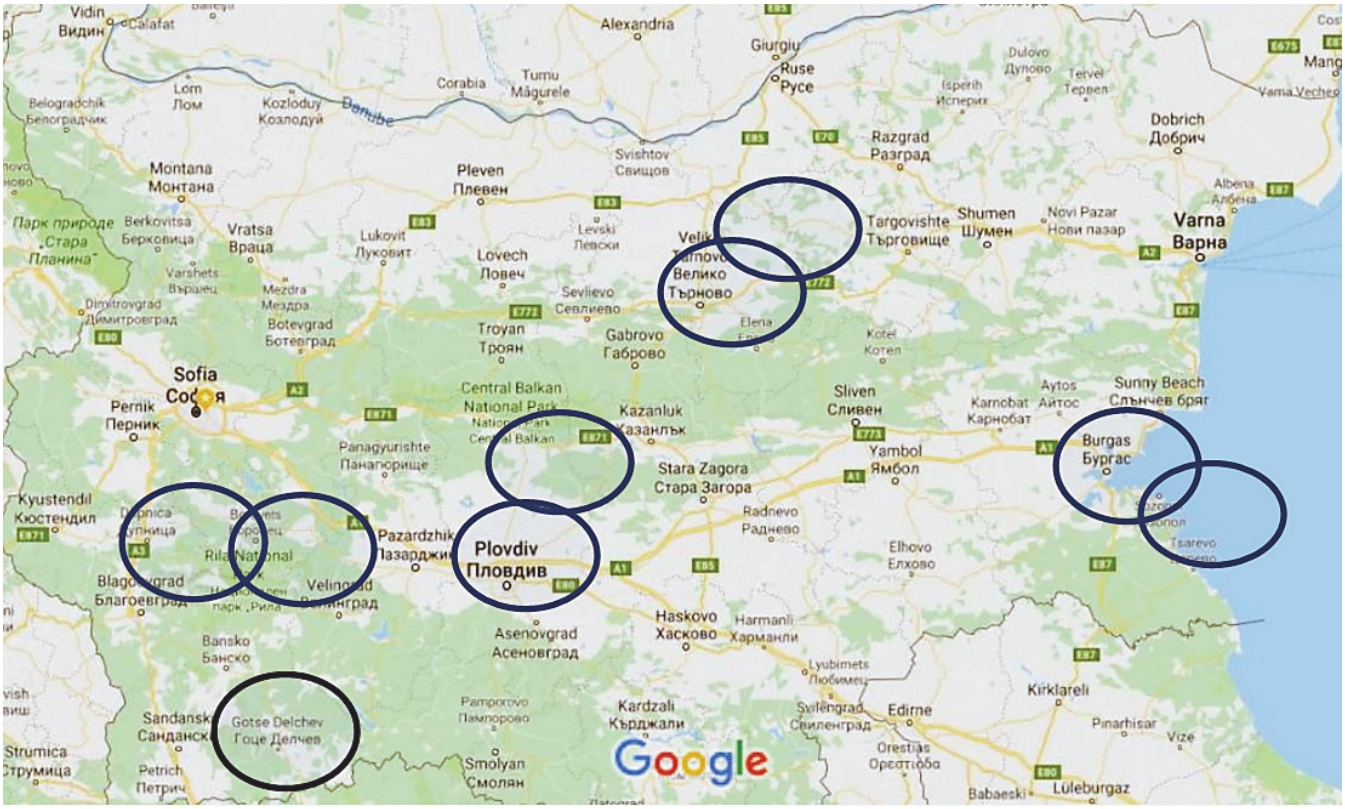


Fig. 1. Map of Bulgaria with surveyed agro-ecosystems
Source: Google maps

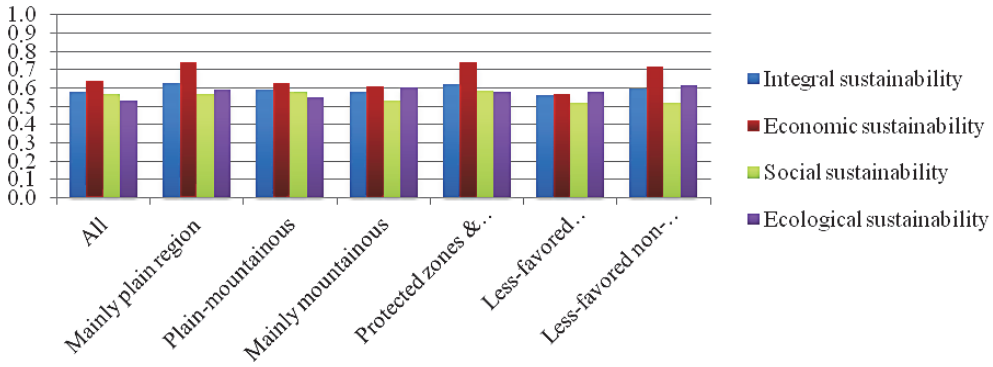


Fig. 2. Level of sustainability in generic types of agro-ecosystems in Bulgaria
Source: interviews with managers of farms, 2017 and authors' calculations

and social aspects are below the average for the country (respectively 0.61 and 0.53), the level of ecological sustainability is among the highest (0.6). The agricultural sustainability in the protected zones and territories is above the average (0.62), these ecosystems have relatively high economic sustainability (0.74), the highest level of social sustainability (0.59) and good levels for ecological sustainability (0.58). The ecological sustainability in the plane-mountainous regions is the lowest in the country (0.55), and for the non-mountainous regions with natural restrictions it is the highest (0.61).

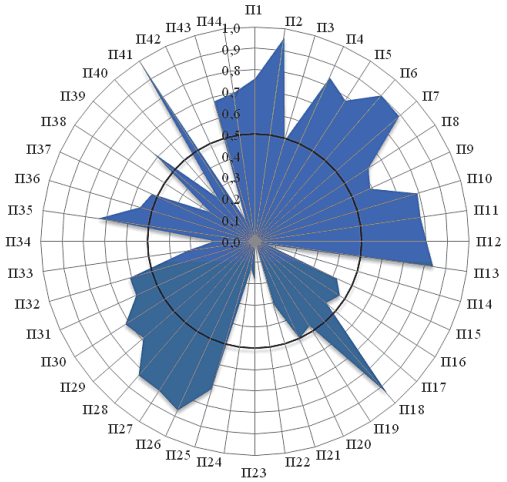
The agriculture of ecosystems in the plane regions has high significances for economic sustainability for the indicators: share of own capital in the total capital, labour productivity, livestock productivity, and share of sold production in the total output (Fig. 3). The social sustainability of the sector in these regions is high in relation to degree of correspondence to the normative labour conditions, education level of manager, and share of unoccupied seasonal labour positions in the total number of employed. Agriculture in such regions is with ecologically strong sustainability for the dynamics of Utilised Agricultural Area (UAA) in the last 5 years, the dynamics of the raised livestock number in the last 5 years, and keeping the norms of animal welfare.

Simultaneously, the levels of some indicators in the plane agro-ecosystems have low levels. While the economic sustainability is satisfying only regarding the relation profit/ production costs, for the social sustainability satisfactory are the levels for number of family members working in the farm, manager's age, participation in training programs in the last 3 years, share of employed with special agricultural education/ qualification, and number of participation in professional organizations and initiatives. Along with that, regarding the public position of the farmer, manager or owner, and participation in local initiatives the state is unsatisfactory, while for presence of family member ready to take-over the farm on the limit of the unsustainability. Moreover, according the indicator share of hired workers, members of trade unions, the state is unsustainability. The ecological sustainability of the sector in these regions is satisfying in relation to the share of arable land in the total agricultural land, presence of protected species on the farm territory, and number of cultural species; and unsatisfying for the keeping of practices for landscape maintenance, and implementation of principles for organic production.

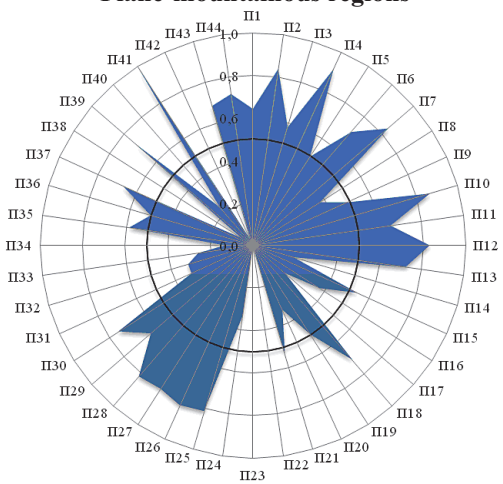
In ecosystems of plane-mountain regions the economic sustainability of agriculture is high regarding the: share of own capital in the total, labour productivity, and share of sold production in the total output (Fig. 3). The highest in social aspect in these regions are the indicators: net farm income/average income in the region, degree of satisfaction from the farming activity, share of non-occupied permanent work positions in the total number of employed, and share of unoccupied seasonal work positions in the total number of employed. From ecological aspect, the best of these ecosystems are only the dynamics of the number of livestock in the last 5 years, and the keeping of norms of animal welfare.

At the same time agro-ecosystems in the plain-mountainous regions have satisfying values of economic sustainability for the growth of sales in the last 3 years, and investments growth in the last 5 years. The social sustainability in these regions is on satisfying levels in relation to manager's age, degree of participation of women in the farm management, and participation in local initiatives; unsatisfying regarding the presence of family member, ready to take the farm, and participation in training programs in last 3 years; and socially unstable for the share of hired workers, members of trade unions and public positions of the farmer, manager or owner. In the plane-mountain ecosystems the

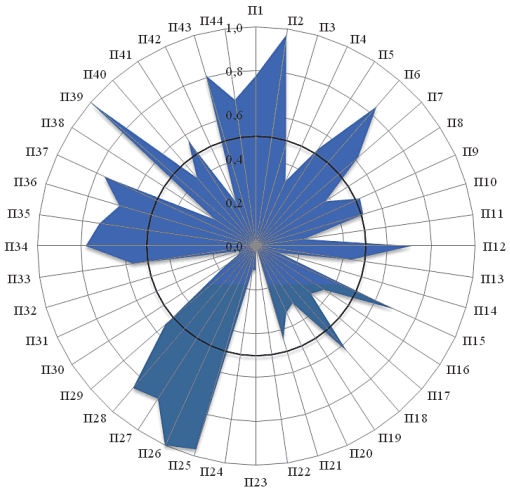
Predominantly plane regions



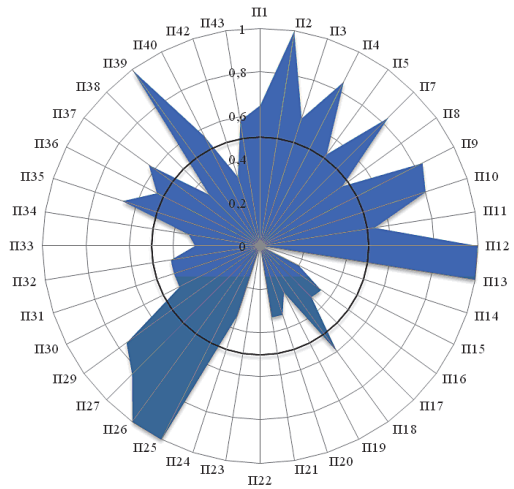
Plane-mountainous regions



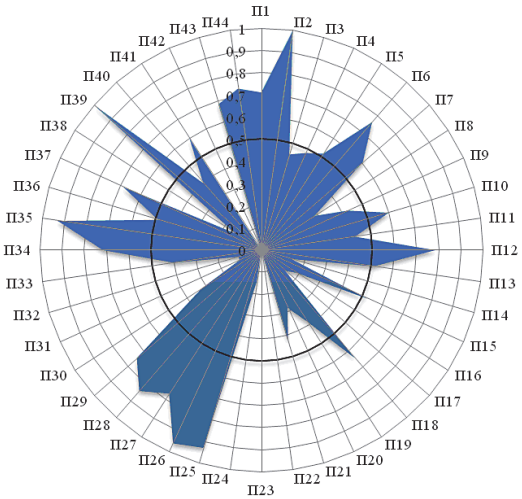
Predominantly mountainous regions



Protected zones and territories



Mountainous with natural restrictions



Non-mountain with natural restrictions

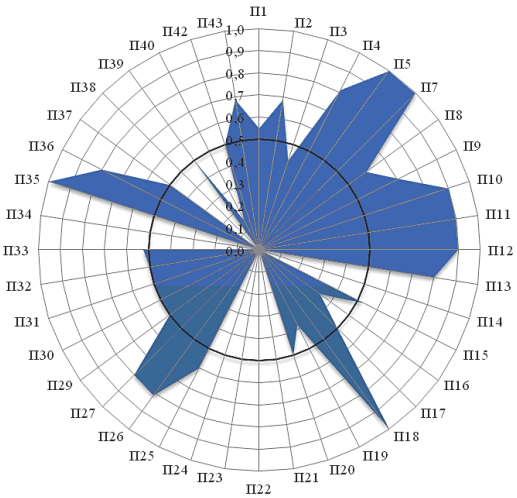


Fig. 3. Indicators* for sustainability in generic type agro-ecosystems in Bulgaria →

→ Fig. 3.

*П1 – Direct payments in the net income; П2 – Share of own capital in the total one; П3 – Profit/production costs; П4 – Labour productivity; П5 – Land productivity; П6 – Livestock productivity; П7 – Share of sold production in the total one; П8 – Sales growth in the last three years; П9 – Investments growth in last 5 years; П10 – Net farmer's income/ average income in the region; П11 – Payment of hired labour/ average income in the region; П12 – Degree of satisfaction from farmer's activity; П13 – Degree of compliance to normative labour conditions; П14 – Presence of a family member ready to take the farm; П15 – Number of family members working in the farm; П16 – Age of manager; П17 – Participation of training programs in the last 3 years; П18 – Education level of manager; П19 – Share of occupied with special agricultural education / qualification; П20 – Degree of participation of women in the farm management; П21 – Number of participation in professional organizations and initiatives; П22 – Share of hired workers, members of trade unions; П23 – Public positions occupied from the farmer, manager and owner; П24 – Participation in local initiatives; П25 – Share of non – occupied permanent work positions in the total number of employed; П26 – Share of non – occupied seasonal work positions in the total number of employed; П27 – Change of UAA in last 5 years; П28 – Change of livestock number in last 5 years; П29 – Soil erosion; П30 – Compliance of nitrate fertilization to norms; П31 – Compliance of potassium fertilization to norms; П32 – Compliance of phosphorus fertilization to norms; П33 – Share of arable land in the total UAA; П34 – Keeping the practices of landscape maintenance; П35 – Degree of pollution of underground waters with nitrates; П36 – Level of fuel consumption; П37 – Level of electricity consumption; П38 – Presence of protected species on the farm territory; П39 – Natural biodiversity protection; П40 – Number of cultural species; П41 – Respecting of animal welfare norms; П42 – Implementation of principles for organic production; П43 – Yield variation of main crops for 5 years; П44 – Percentage of mortality of livestock for 5 years

Source: interviews with managers of farms, 2017 and authors' calculations

ecological sustainability is satisfying regarding the compliance with the norms of the fertilization with potassium, compliance with the norms of phosphorus fertilization and share of arable land in the total agricultural land; unsatisfying for the keeping of practices for landscape maintenance, presence of protected species on the farm territory, and number of cultural species; and unstable for the implementation of principles for organic production.

The agricultural sustainability in ecosystems in mountain regions has the highest values for the economic indicators: share of own capital in the total capital, and livestock productivity; the social indicators of the share of non-occupied permanent work positions in the total number of employed, and share of unoccupied seasonal work positions in the total number of employed; and ecological indicators: dynamics of UAA in last 5 years, dynamics of raised livestock in last 5 years, natural biodiversity protection, and yield variation of the main crops for 5 years (Fig. 3). In mountain regions with satisfying values for sustainability are the economic relation profit/ production costs, labour productivity, and sales' growth in last 3 years. The social sustainability of this type of ecosystems is satisfying in lots of indicators: degree of compliance with normative labour conditions, manager's age, participation in training programs in last 3 years, share of employed with special agricultural education/ qualification, degree of participation of women in the farm management, and number of participations in professional organizations and initiatives. Furthermore, the social sustainability is unsatisfying in relation to the payment of hired labour/ average income in the region, presence of a family member, ready to take the farm, public position of the farmer, manager or owner, and participation in local initiatives. In relation to the share of hired workers, members of trade unions, there is a social instability. In the mountain agro-ecosystems the ecological sustainability is on a satisfying level for the number of cultural species, and unsatisfying for the compliance with the norms of nitrate fertilization, compliance with the norms for potassium fertilization, compliance of phosphorus fertilization with the norms, presence of protected species on the farm territory, and implementation of principles for organic production.

The ecosystems' agricultural sustainability in the protected zones and territories is economically high regarding the share of own capital in the total one, labour productivity, share of sold production in the total output, and investments' growth in the last 5 years (Fig. 3). This ecosystem type has strong social stability for the degree of satisfaction of the farming activity, degree of compliance with the normative labour conditions, share of unoccupied permanent work positions in the total number of employed, and share of non-occupied seasonal work positions in the total number of employed. In ecological aspect the agricultural sustainability in the protected zones and territories is high only regarding the dynamic of UAA in last 5 years, and natural biodiversity protection. On the other hand, the economic sustainability of agro-ecosystems with protected zones and territories is satisfying for the sales' growth in the last 3 years, while for the livestock productivity there is an instability. The social sustainability in these zones and territories is on satisfying level in relation to manager's age, participations in training programs in last 3 years, degree of participation of women in the farm management, number

of participations in professional organizations and initiatives, and participation in local initiatives. For the social indicators the number of family members working in the farm, and share of employed with special agricultural education/ qualification the sustainability level is unsatisfying. Moreover, regarding the presence of family member ready to take the farm, the share of hired workers, members in trade union and the public position of the farmer, manager or owner, the ecosystems are unsustainable. In protected zones and territories some ecological indicators are also relatively low (unsatisfying): compliance to norms of the fertilization with potassium, compliance to norms of the fertilization with phosphorus, share of arable land in the total agricultural land, keeping of practices for landscape maintenance, presence of protected species on the farm territory, and implementation of principles for organic production.

Agricultural sustainability in ecosystems of mountain regions with natural restrictions are highly economically sustainable just in relation to the share of own capital in the total; strongly socially sustainable for the share of unoccupied permanent work positions in the total number of employed, and share of unoccupied seasonal work positions in the total number of employed (0.96); and highly ecologically sustainable according the dynamics of livestock number in last 5 years, degree of pollution of underground waters with nitrates, and protection of natural biodiversity (Fig. 3). At the same time, some economic indicators of sustainability in these ecosystems are on satisfying level, as: profit/ production costs, labour productivity, sales' growth in last 3 years, and investments' growth in last 5 years. Similarly, the social sustainability of this ecosystems' type is satisfying regarding: payment of hired labour/ average income in the region, share of employed with special agricultural education/ qualification, degree of participation of women in the farm management, and number of participations in professional organizations and initiatives. The level of social sustainability in such regions is unsatisfying for presence of family member, ready to take the farm, manager's age, participation in training programs in last 3 years, and participation in local initiatives. In relation to the share of hired workers, members of trade unions and public position of manager, farmer and owner, the mountain regions with natural restrictions are socially unsustainable. In these regions some indicators for ecological sustainability have satisfying levels, as the compliance to norms of the nitrate fertilization, share of arable land in the total agricultural land, level of fuel consumption, and number of cultural species. The ecological sustainability is unsatisfying for the compliance to the norms of potassium fertilization, compliance to norms of phosphorus fertilization, and presence of protected species on the farm territory, while for the principles of organic production implementation, they are unsustainable.

The agricultural sustainability in the non-mountain regions with natural restrictions is economically high regarding the labour productivity, land productivity, and share of sold output in the total one (Fig. 3). In relation to the social sustainability, the indicators are high for: net farm income/ average income in the region, payment of hired work in the region, degree of satisfaction from the farming activity, education level of manager, and share of unoccupied seasonal work positions in the total number of employed. The ecological sustainability in these regions is high only for the pollution of underground waters with nitrates. The agro-ecosystems in the non-mountain regions with natural

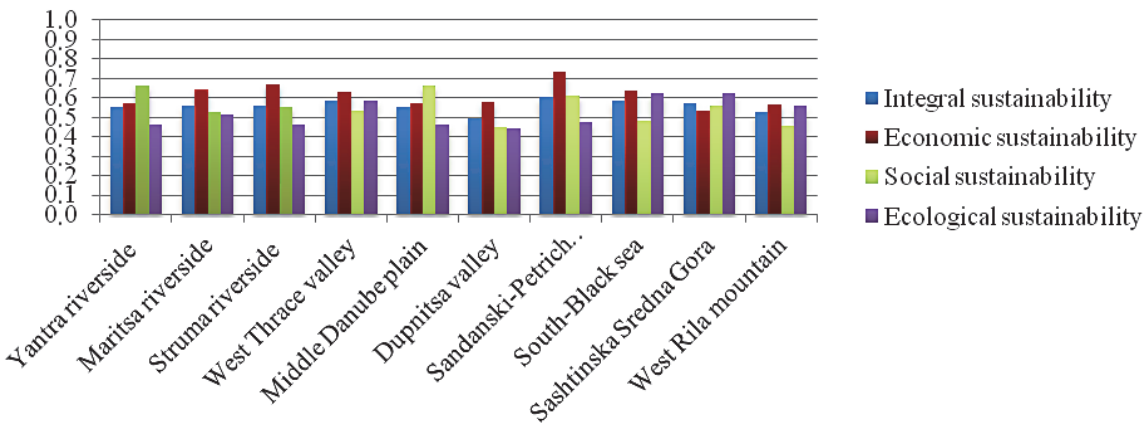


Fig. 4. Levels of sustainability in the specific agro-ecosystems in Bulgaria
Source: interviews with managers of farms, 2017 and authors' calculations

restrictions have satisfying economic sustainability only regarding the ratio profit/ production costs. The social sustainability of these agro-ecosystems is satisfying for the age of manager, and share of employed with special agricultural education/ qualification. As regards to the presence of family member ready to take the farm; number of participation in professional organizations and initiatives; share of hired workers, members of trade unions; public position of farmer, manager or owner and participation in local initiatives, these ecosystems are unsustainable. Non-mountain regions with natural restrictions have unsatisfying level of ecological sustainability for the indicator number of cultural species, and they are ecologically unsustainable as regards the keeping of landscape maintenance practices, and presence of protected species on the farm territory.

The assessment also demonstrated that there is a big variation in the levels of integral, economic, social and ecological sustainability of the specific agro-ecosystems. From the analyzed 10 agro-ecosystems, the highest integral sustainability has Sandanski-Petrich hollow (0.61), with economic sustainability with highest values (0.73), social sustainability with also high values (0.61), while the ecological sustainability is among the lowest in the country and on satisfying level (0.47) (Fig. 4). On the other hand, the integral sustainability of agriculture in Dupnitsa hollow is on the lowest level (0.49) and the only one with satisfying level among the analyzed ecosystems. In this ecosystems the levels of social (0.45) and ecological (0.45) sustainability are satisfying and the lowest among the analyzed.

The integral sustainability of agro-ecosystems in the areas alongside the rivers Yantra, Maritsa and Struma is on a relatively low (under the average) level – respectively 0.55, 0.56 и 0.56. However, there is a big differentiation of different aspects of sustainability in these specific ecosystems. For the eco-system alongside Struma River the economic sustainability is on a high level (0.67), while for Yantra riverside it is slightly below the average for the country. On the other hand, the area alongside Yantra has the highest level of social sustainability (0.66), whereas the area alongside Maritsa has the lowest social sustainability and close to the limit of the satisfying level (0.52). For the three riverside ecosystems the ecological sustainability of the sector is below the average values for the country, as for Maritsa riverside the value is on the border of the satisfying level (0.51), and for the other riverside ecosystems – on satisfying level (by 0.46).

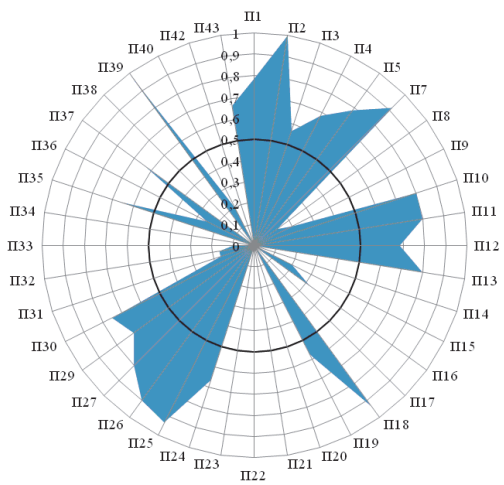
The agro-ecosystem Middle Danube plain has relatively low integral sustainability (0.55), with levels of social sustainability among the highest in the country (0.66), and from ecological aspect on the satisfying level (0.46) and among the lowest for the country. The agriculture in the West Thrace valley has integral sustainability on a relatively high level and over the average for the country (0.59). This agro-ecosystem has good economic sustainability, over the average (0.67), with one of the highest levels of ecological sustainability (0.59), but relatively low and under the average social sustainability (0.54).

Both analyzed specific mountain agro-ecosystems have lower integral sustainability than the average – respectively 0.57 for Sashtinska Sredna Gora, and 0.53 for West Rila Mountain. The social (0.56) and the ecological (0.63) sustainability of Sashtinska Sredna Gora are higher than the values of West Rila mountain (respectively on satisfying level 0.46 and good level 0.56), whereas for the economic sustainability is the opposite (0.53 and 0.57). Sashtinska Sredna Gora and South Black sea cost have the highest indicators for ecological sustainability among all analyzed specific ecosystems in the country. The integral sustainability of agriculture of South Black sea is on the average level for the country – 0.58, while the economic sustainability is on a middle level (0.64), the social sustainability is satisfying (0.48), and the ecological is the best of all analyzed (0.63).

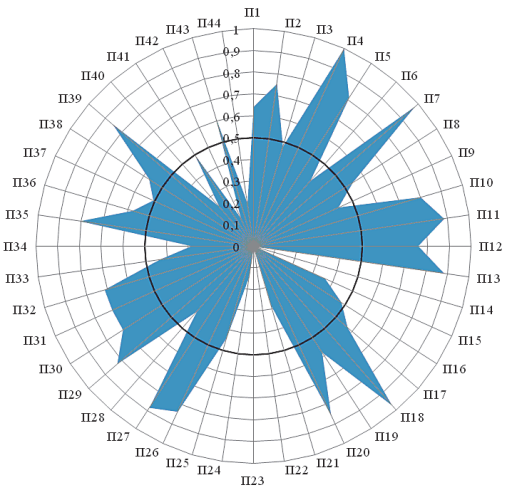
There is a considerable variation of different indicators' levels in the specific agro-ecosystems. Three specific riverside ecosystems in North Central, South Central and South-West regions were analyzed. In the agro-ecosystem of Yantra river high levels have only the indicators for economic sustainability – share of own capital in the total one, and share of sold production in the total output; the indicators for social sustainability – level of education of the manager, number of participations in professional organizations and initiatives, share of unoccupied permanent work positions in the total number of employed, and share of unoccupied seasonal work positions in the total number of employed; and for the ecological sustainability – natural biodiversity protection (Fig. 5).

The agriculture of Yantra riverside has unsatisfying sustainability for lots of indicators: economic growth of sales in the last 3 years, and investments' growth in the last 5 years; social number of family members, working in the farm; and ecological: compliance of potassium fertilization to the norms, compliance to the norms of phosphorus fertilization, level of fuel consumption, and number of cultural species. Moreover, this system is unsustainable due to lots of social and ecological indicators: presence of a family member, ready to take the farm; participation in training programs in last 3 years; degree of participation of women in the farm management, share of hired workers, members of trade unions; public position, occupied by the farmer,

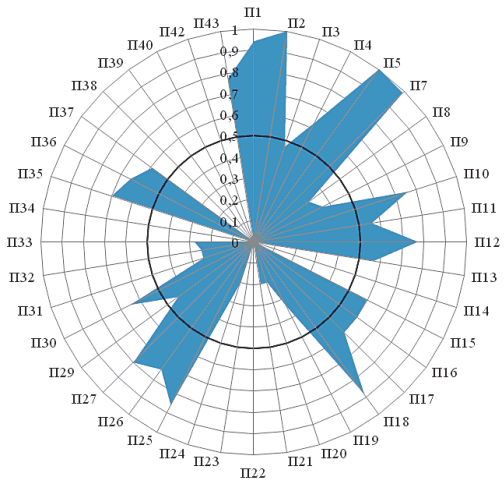
Yantra riverside



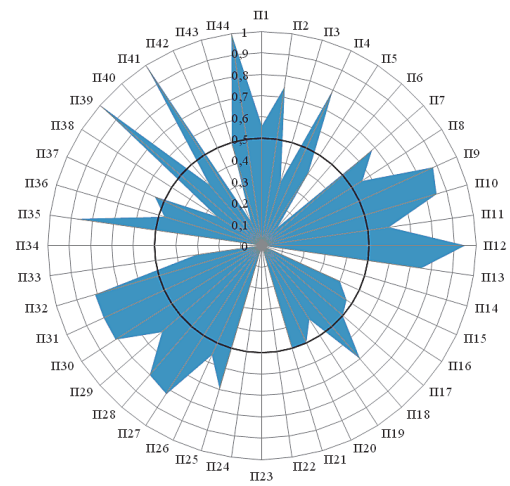
Maritsa riverside



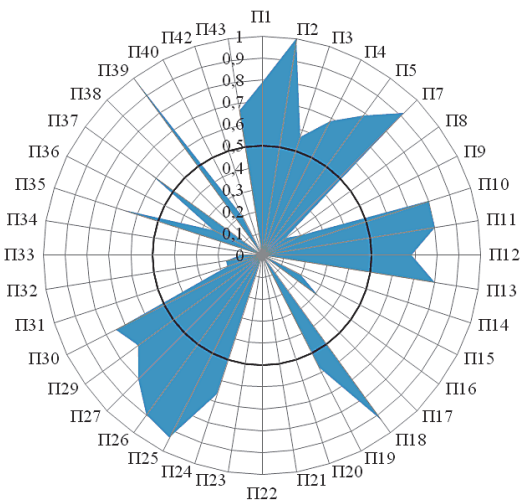
Struma riverside



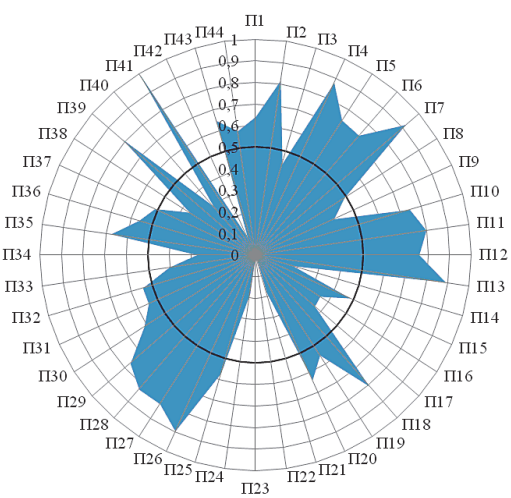
South-Black Sea



Middle Danube plain



West Thrace valley



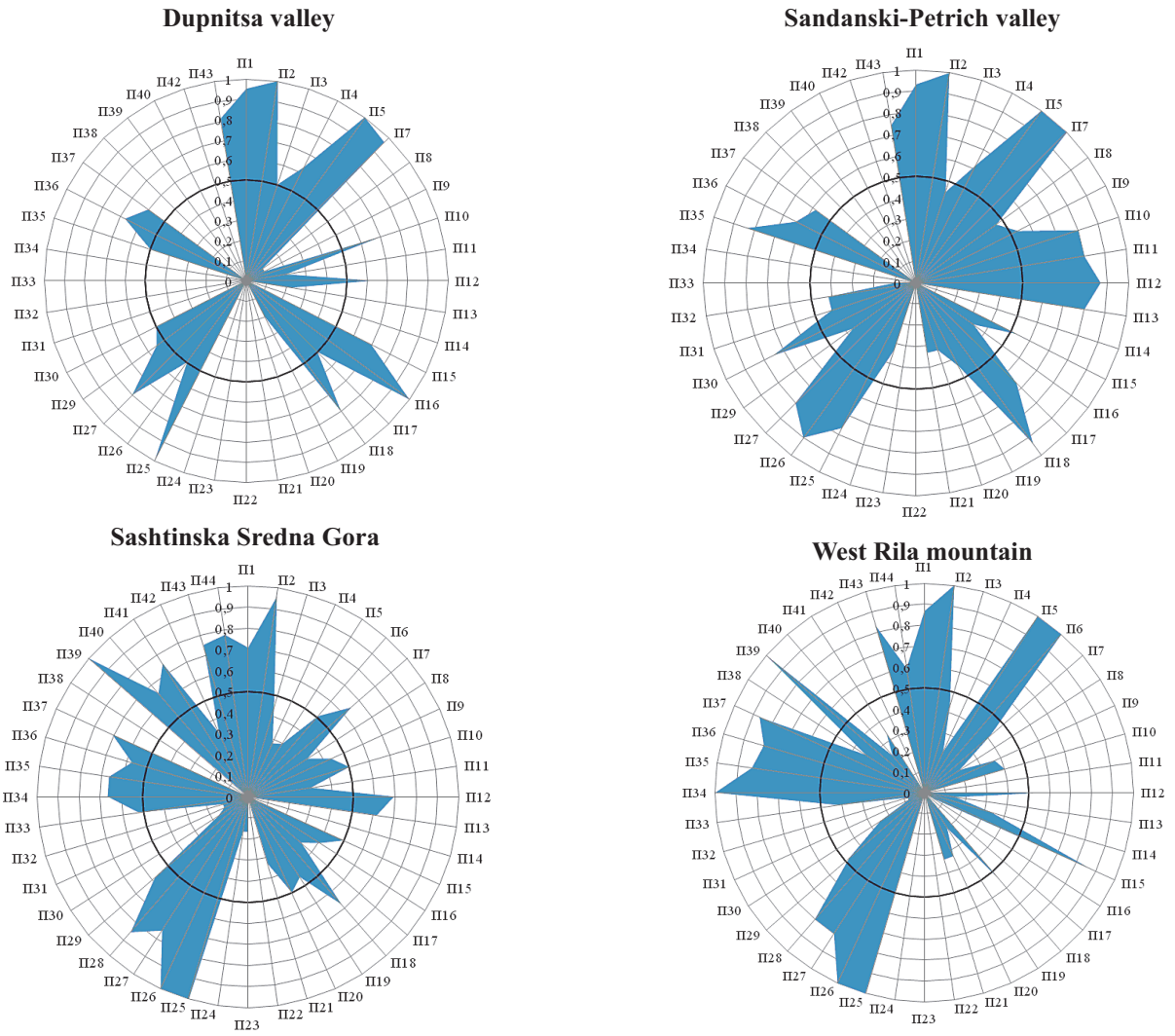


Fig. 5. Indicators for agricultural sustainability in specific agro-ecosystems in Bulgaria
Source: interviews with managers of farms, 2017 and authors' calculations

manager or owner; share of arable land in the total agricultural land; keeping of practices for landscape maintenance; presence of protected species on the farm territory; implementation of principles for organic production. In relation to the age of manager, the social sustainability is satisfying. Similar to indicators of the agro-ecosystem along Yantra riverside are the indicators for the sustainability of Middle Danube plain.

The agriculture in the other analyzed riverside ecosystem, of Maritsa, is characterized by several indicators for levels of high sustainability: economic – labour productivity, land productivity, and share of sold production in the total production; social – payment of hired labour/average income in the region, degree of compliance to normative labour conditions, education level of the manager, degree of participation of women in the farm management, share of unoccupied seasonal work positions in the total number of employed; and ecological – dynamics of UAA in the last 5 years, soil erosion, degree of pollution of underground waters with nitrates, and natural biodiversity protection (Fig. 5).

The agro-ecosystems from the riverside of Maritsa have satisfying sustainability of economic indicators: profit/production costs, livestock productivity, and investments' growth in the last 5 years. The level of social indicators is also satisfying: number of family members, working in the farm, manager's age, number of participations in professional organizations and initiatives, and share of unoc-

cupied permanent work positions in the total number of employed. Similar is the level of ecological indicators: dynamics of the arable land in the last 5 years, and share of arable land in the total agricultural land. The agricultural sustainability alongside Maritsa river is on unsatisfying level about the social and ecological indicators: participation in local initiatives, keeping of practices for landscape maintenance, number of cultural species, implementation of principles for organic production, and percentage of mortality of the livestock for 5 years. In relation to social dimensions there is a state of unsustainability: presence of family member ready to take the farm, share of hired workers, members in professional organizations and public position of the farmer, manager or owner.

Unlikely the other two riverside agro-ecosystems, this of Struma river has high economic levels of sustainability for the share of direct payments in the net income, share of own capital in the total one, land productivity, and share of sold production in the total output (Fig. 5). The social sustainability in this agro-ecosystem is high only regarding the education level of the manager, and share of unoccupied work positions in the total number of employed. On the other hand, some indicators of economic sustainability in this agro-ecosystem have satisfying levels, as: profit/ production costs, growth of sales in the last 3 years, and investments' growth in the last 5 years. Similar is the level of sustainability regarding the social and ecological indicators for the employed with special agricultural education/ qualification, soil erosion, and share of arable land in the total agricultural land.

Moreover, the agricultural sustainability of Struma riverside is unsustainable in relation to the social measurers: degree of participation of women in the farm management, number of participation in professional organizations and initiatives, and participation in local initiatives; and ecological indicators: compliance to the norms of potassium fertilization, compliance to the norms of phosphorus fertilization, and number of cultural species. This agro-ecosystem is socially unsustainable in relation to the participation of a family member, ready to take the farm; share of hired workers, members in trade unions and public position of the farmer, manager or owner. The ecosystem is also in state of ecological unsustainability regarding the keeping of practices for landscape maintenance, presence of protected species on the farm territory, protection of the natural biodiversity, and implementation of principles of organic production.

The agricultural sustainability in the South-Black sea ecosystem has high levels for the economic indicator – investments' growth in the last 5 years, and for the social indicators: net farm income /average income in the region, and degree of satisfaction from farming activity (Fig. 5). The agro-ecosystem is also ecologically sustainable with lots of indicators: dynamics of UAA in the last 5 years, compliance to the norms of nitrate fertilization, compliance to the norms of the potassium fertilization, compliance to the norms of the phosphorus fertilization, degree of pollution of underground waters with nitrates, natural biodiversity protection, keeping the norms of animal welfare, and percentage of mortality for the livestock for 5 years. The agro-ecosystem South-Black sea has satisfying sustainability concerning the economic indicator profit/ production costs; several social indicators, as: number of family members working in the farm, manager's age, and share of employed with special agricultural education/ qualification; and ecological indicators for: share of arable land in total agricultural land, level of fuel consumption, and number of cultural species.

This specific ecosystem has unsatisfying sustainability of agriculture regarding the economic aspect for livestock productivity, and from ecological aspect: for the presence of protected species on the farm territory, and implementation of organic production principles. The agriculture of South-Black Sea is socially unsustainable regarding the presence of a family member ready to take the farm; share of workers, members of trade unions; public position of the farmer, manager or owner and participation in local initiatives, and in ecological aspect, for the keeping of practices for landscape maintenance.

The agriculture in the West Thrace valley has high economic sustainability regarding the indicators share of own capital in the total one, labour productivity, and share of sold production in the total; high social sustainability for compliance to the normative labour conditions, and share of unoccupied seasonal work places in the total number of employed; and high ecological sustainability for the dynamics of UAA in the last 5 years, dynamics of the livestock number in the last 5 years, natural biodiversity protection, and keeping of norms for animal welfare (Fig. 5). The agriculture of this ecosystem has satisfying levels of economic sustainability for: profit/ production costs, and investments' growth in the last 5 years; social sustainability for: number of family members working in the farm, manager's age, participation in training programs in last 3 years; and ecological sustainability for: share of arable land in the total agricultural land, keeping of practices for landscape maintenance, presence of protected species on the farm territory, and number of cultural species.

The social sustainability is unsatisfying for indicators: presence of family member ready to take the farm, number

of participations in professional organizations and initiatives, and participation in local initiatives, and regarding the share of hired, members of trade unions, and public position of farmer, manager or owner the state is unsustainable. The same state has the ecological sustainability regarding the implementation of principles for organic production.

In the South-West region of the country have been analyzed two specific agro-ecosystems of Dupnitsa valley and of Sandanski-Petrich valley. Dupnitsa valley has high economic sustainability of indicators: share of direct payments in the net income, share of own capital in the total one, land productivity, and share of sold output in the total (Fig. 5). The agriculture in this ecosystem has high social and ecological sustainability only regarding the age of the manager, share of unoccupied permanent work positions in the total number of employed, and variation of yields of the main crops for 5 years.

Under two economic, several social and one ecological indicator, the sustainability of this agro-ecosystem is unsatisfying: sales growth in last 3 years, investments' growth in last 5 years, payment of hired labour/average income in the region, degree of compliance to normative labour conditions, and share of employed with specific agricultural education/qualification, and number of cultural species. Under many social and ecological indicators the level is unsustainable: presence of a family member ready to take the farm; degree of participation of women in the farm management; number of participations in professional organizations and initiatives; share of hired workers, members of trade unions; public position of the farmer, manager or owner; participation in local initiatives; compliance to the norms of potassium fertilization; compliance to the norms of phosphorus fertilization; respecting of practices for the landscape maintenance; presence of protected species on the farm territory; protection of natural biodiversity and implementation of organic production principles.

Other analyzed agro-ecosystem is Sandanski-Petrich valley, which is characterized by high sustainability of economic indicators: share of direct payments in the net income, share of own capital in the total, land productivity, and share of sold output in the total output; social measurers: degree of satisfaction from farm activity, education level of manager, and share of unoccupied seasonal work positions in the total number of employed; and ecological indicator: degree of pollution of underground waters with nitrates. In this ecosystem the agricultural sustainability has relatively low (satisfying) economic sustainability according two indicators: profit/ production costs, and growth of sales in the last 3 years. Similarly, the social sustainability in the agro-ecosystem has satisfying levels in relation to: manager's age; share of employed with special agricultural education/ qualification; degree of participation of women in the farm management; number of participation in professional organizations and initiatives, and participation in local initiatives. The agriculture in this area is socially unsustainable regarding the presence of a family member, ready to take the farm; share of hired workers, members of trade unions and public position of the farmer, manager or owner.

Apart this, the ecological sustainability of Sandanski-Petrich valley is satisfying for the soil erosion; compliance to norms of potassium fertilization, and compliance to norms of phosphorus fertilization; unsatisfying regarding the share of arable land in the total agricultural land, and number of cultural species; and ecologically unsustainable regarding the keeping of practices for landscape maintenance; presence of protected species on the farm territory; protection of natural biodiversity and implementation of organic production principles.

Two mountain agro-ecosystems have been analyzed – Sashtinska Sredna Gora and Western Rila Mountain. The agriculture in Sashtinska Sredna Gora is economically sustainable regarding the share of own capital in the total; strongly socially sustainable for the share of unoccupied permanent work positions in the total number of employed, and share of unoccupied seasonal work positions in the total number of employed; and highly ecologically sustainable for the dynamics of the livestock number in the last 5 years, and for the natural biodiversity protection (Fig. 5). The agricultural production in this ecosystem has satisfying levels of many economic and social indicators: profit/production costs, labour productivity, land productivity, sales growth in last 3 years, investments growth in last 5 years, payment of hired labour/average income in the region, manager's age, participation in education programs in last 3 years (0.33), share of employed with special agricultural education/qualification, and number of participations in professional organizations and initiatives. This agro-ecosystem has satisfying ecological sustainability in relation to the implementation of organic production principles.

Moreover, according several social and ecological indicators the agriculture in Sashtinska Sredna Gora is with unsatisfying sustainability: public position of the farmer, manager or owner, participation in local initiatives, compliance to norms of the nitrate fertilization, compliance to norms of the potassium fertilization, compliance to norms of the phosphorus fertilization. This agro-ecosystem is socially and ecologically unsustainable in relation to the presence of a family member, ready to take the farm; share of

hired workers, members of trade unions and presence of protected species on the farm territory.

The other mountain agro-ecosystem Western Rila mountain has high economic sustainability in relation to the share of direct payments in the net income, share of own capital in the total, land productivity, and livestock productivity (Fig. 5). The social sustainability is strong regarding the indicators: number of family members working in the farm, share of unoccupied permanent work positions in the total number of employed, and share of unoccupied seasonal work positions in the total number of employed. The agriculture in Western Rila Mountain is ecologically sustainable for the respecting of practices for landscape maintenance, degree of pollution of underground waters with nitrates, level of consumption of electricity, protection of natural biodiversity, and variation of yields of main crops for 5 years. This agro-ecosystem has satisfying economic sustainability in relation to profit/production costs, share of sold output in the total output, and investments growth in last 5 years. The level of social sustainability is satisfying for the net farm income/average income in the region, presence of a family member, ready to take the farm, degree of participation of women in the farm management, and number of participation in professional organizations and initiatives. The agricultural sustainability is unsatisfying regarding the economic indicators labour productivity, and sales growth in the last 3 years; and social indicators degree of compliance to normative labour conditions, and share of employed with special agricultural education/ qualification. Furthermore, some social indicators in this agro-ecosystem have unsustainability levels: payment of hired labour/average income in the region, manager's age, participation in education programs in the last 3 years, share of hired workers, members in trade unions, public positions of the farmer, manager or owner, participation in local initiatives.

The agro-ecosystem Western Rila Mountain has satisfying ecological sustainability for: soil erosion, share of arable land in the total agricultural land, presence of protected species on the farm territory, and respecting the norms for animal welfare. The ecological sustainability of the ecosystem is unsatisfying for: compliance to norms of nitrate fertilization, number of cultural species, compliance to norms of potassium fertilization, and compliance to norms of phosphorus fertilization. This ecosystem is ecologically unsustainable in relation to the principles of organic production.

Finally, we compared the integral agrarian sustainability based on the assessment of sustainability of agro-ecosystems with the results of previous studies assessing agrarian sustainability with the aggregate sectoral (statistical, etc.) data (Bachev et al., 2017). The multi-indicator assessment of agricultural sustainability derived from agro-ecosystems integration in the four analyzed regions shows that the overall sustainability is 0.58, which expresses a good sustainability level of agriculture (Fig. 6). The biggest value has the indicator of economic sustainability (0.64), the social sustainability shows lower value (0.57), and the ecological sustainability is close to the unsatisfying value level (0.53). Therefore, integral assessment results based on the micro agro-ecosystems (farm) data are similar with the results based on aggregated sectoral (statistical, etc.) data. It means that both approaches are reliable and could be simultaneously used for assessing agrarian sustainability at various level – sector, subsector, region, agro-ecosystem, and farm.

The analysis of private indexes on basic principles, criteria and indicators of the sustainability in the analyzed 4 administrative and geographical regions (larger agro-ecosystems) of the country identify components contributing for the levels of different aspects of agricultural sustainability. The assessment ascertained that the ecological sustainability is relatively low due to the fact that the indicators for the principles "land quality" (0.44), "biodiversity" (0.38) and "organic production" (0.11) are low (Fig. 7). Thus, the improvement of these low levels of above-mentioned principles is a factor for maintenance and raising of ecological

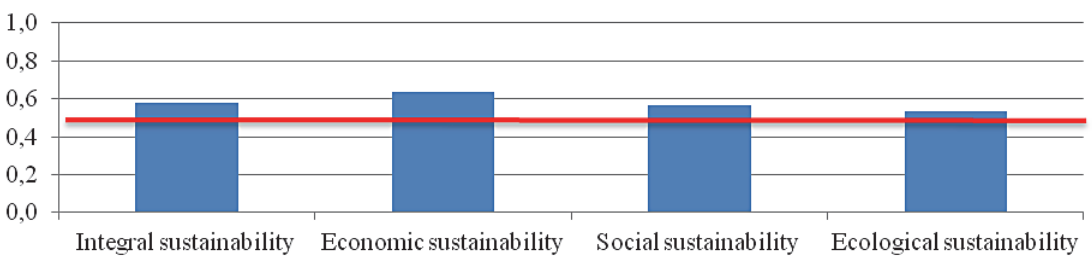


Fig. 6. Indicators of integral, economic, social and ecological sustainability of analyzed agro-ecosystems in 4 geographical regions of Bulgaria

Source: interviews with managers of farms, 2017 and authors' calculations

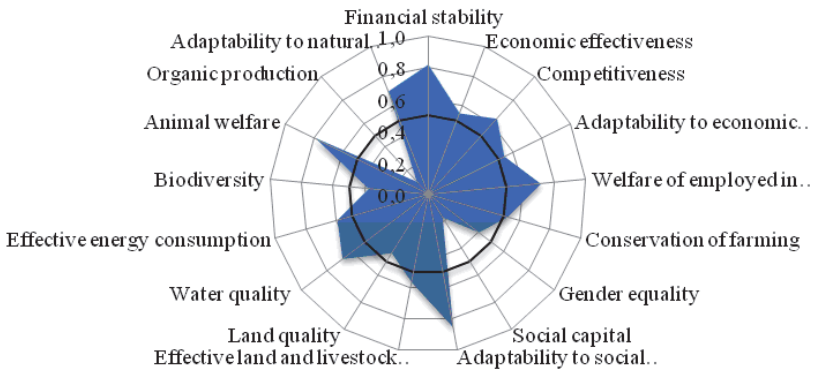


Fig. 7. Sustainability index according the sustainability principles in analyzed agri-ecosystems in 4 geographical regions of Bulgaria

Source: interviews with managers of farms, 2017 and authors' calculations

and integral sustainability in the sector. Also it becomes clear that despite the relatively high integral economic sustainability, the indicator of adaptability to economic environment is relatively low (0.54) and critical for maintaining the reached level. Analogically, for the social sustainability improvement would contribute mostly the increase of low levels of indicators for the principles "farming conservation" (0.52), "gender equality" (0.40) and "social capital" (0.17).

The profound analysis according different criteria and indicators gives opportunity for detailed analysis of elements contributing for/or decrease the agricultural sustainability level. For example, the low levels of ecological sustainability are determined from the low criteria "conservation and improving of soil fertility" (0.46); "balanced land use structure maintenance" (0.35; "landscape elements conservation" (0.30); "natural biodiversity maintenance and improvement" (0.46); "cultural biodiversity maintenance and improvement" (0.29) and "organic production increase" (0.11). The unsatisfying levels according these criteria for ecological sustainability are (pre)determined of low levels of indicators for eco-sustainability, as: insufficient conformity of norms for fertilization with potassium (0.38) and phosphorus (0.38), high share of arable land in the total agricultural land (0.33), low degree of compliance with practices for landscape conservation (0.3), insufficient protected species on farms' territory (0.18), limited number of cultural species in farms (0.29) and low degree of application of organic production principles (0.11).

Social sustainability in agriculture is usually decreased almost by: lack of family member, ready to continue the farm work (for individual and family farms) (0.13), elderly age of managers and farm owners (0.41), insufficient participation in training programs in the last years (0.33), low share of employed with special agricultural education and qualification (0.44), insufficient participation of women in the farm management (0.4), low participation of farms in professional organizations and initiatives (0.43), lack of membership of hired workers in trade unions (0), weak participation in the public governance from the side of farmers, managers and owners (0.1), and insufficient involvement of farms in local initiatives (0.2).

Critical for the keeping and improvement of the sector's economic sustainability are the increase of production profitability (0.52) and the keeping and increase of sales (0.48). The low levels of indicators for sustainability show also the specialized areas for agricultural sustainability improvement through adequate change of farms strategies and/or of public policies in relation to the sustainable development of the sector, of different sub-sectors, ecosystems and farms types. On the other hand, the high levels of some indicators express the absolute and relative advantages of Bulgarian agriculture regarding the sustainable development. On the actual stage they are expressed in: high share of own capital in the total capital of farms (0.92), high share of sold production in the total output (0.81), lower share of non-occupied permanent (0.81) and seasonal (0.88) work places in the total number of employed, increase of UAA (0.82) and livestock number (0.84) in the last years and respect of norms for animal welfare (for the livestock breeding farms) (0.8).

Last but not least important, our study let us identify contribution to sustainability of agro-ecosystems of different sub-sectors of agriculture and type of farming organization. The highest integral sustainability has shown by the mixed livestock-breeding (0.7) and mixed crop-growing

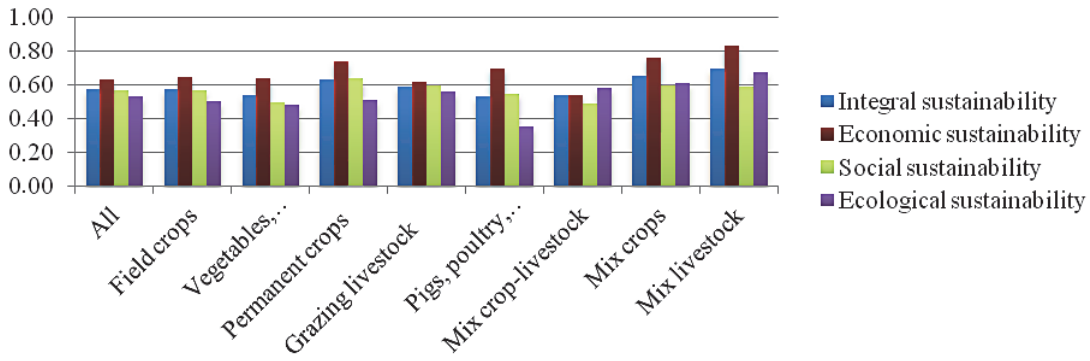


Fig. 8. Contribution to sustainability of agro-ecosystems of different sub-sectors of Bulgarian agriculture
Source: interviews with managers of farms, 2017 and authors' calculations

(0.66) farms, followed by the perennial crops farms (0.63). (Fig. 8). Therefore, the mixed livestock-breeding and crop-growing farms and the farms with perennials contribute in highest degree for improving the integral sustainability of Bulgarian agriculture. From the other hand, the farms specialized in pigs, poultry and rabbits (0.53); vegetables, flowers and mushrooms (0.54) and mixed livestock-crops (0.54) have the lowest integral sustainability. This means that the last mentioned types of farms decrease in a biggest degree the integral sustainability in the country.

Similar to integral sustainability, the sub-sectors with the highest economic sustainability are: mixed livestock breeding (0.84), mixed crop growing (0.76) and perennial crops (0.74). The mixed crop-growing production has the highest ecological sustainability (0.61) and one of the best social sustainability (0.6). The perennial crops sector has high social sustainability (0.64), but lower than the average and almost satisfying ecological sustainability (0.51). The social sustainability of farms specialized in grazing livestock has comparatively high level of social sustainability (0.6). The social sustainability in mixed crop-livestock farms has satisfying level (0.49). The pigs, poultry and rabbits' farms have lowest and satisfying level (0.35), like the farms for vegetables, flowers and mushrooms (0.48). The field crops farms have good but relatively low ecological sustainability (0.5), close to the satisfying level.

Similarly, the agricultural sustainability in different farm types has different levels, which is determined by the specific contribution of different farms for the formation of the existing level of sustainability in the agro-ecosystems of country. Among the farms with different juridical status the trade associations show the highest agricultural sustainability (0.67), contribution the most for the agricultural sustainability of the country. In these organizational and management structures the economic (0.8) and ecological

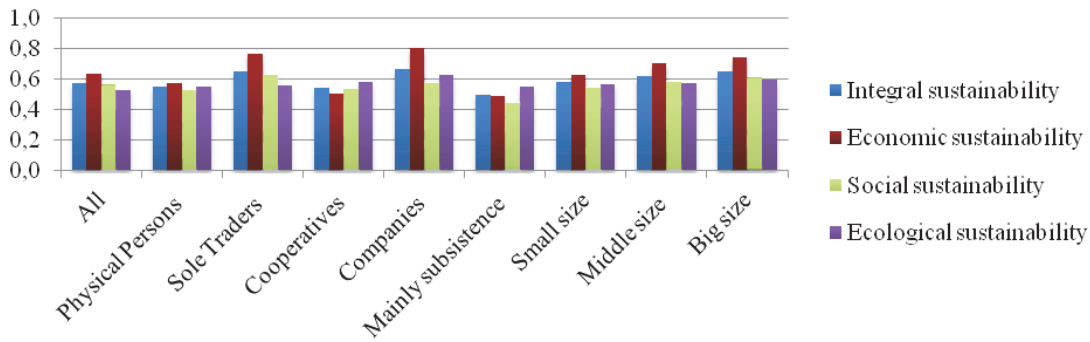


Fig. 9. Contribution to sustainability of agro-ecosystems of farms of different types in Bulgaria
Source: interviews with managers of farms, 2017 and authors' calculations

(0.63) aspects of agricultural sustainability have the highest levels, while the social sustainability is on average for the country level (Fig. 9). The social sustainability is highest for sole traders (0.63), whose integral (0.65) and economic (0.77) sustainability is on the second place and are close to the values of the trade associations.

The agricultural production in cooperatives has the lowest integral sustainability (0.54), which economic sustainability (0.51) is on the border with the satisfying level, and the social sustainability is the lowest, the same level as for individuals (0.53). The cooperatives have ecological sustainability of the production on relatively high level (0.59). The agricultural production of individuals has integral sustainability under the average level (0.55) with lower than the average for the economic (0.58) and social (0.53) sustainability.

The agricultural sustainability in farms with different market orientation and sizes is also characterized by different levels and contribution to the integral agricultural sustainability in the country (Fig. 9). The highest integral sustainability is shown by the large farms (0.65), having the highest economic (0.75), social (0.62) and ecological (0.6) sustainability. Therefore, these farms contribute in biggest degree for the increase of the integral level of agricultural sustainability in the country. In predominantly self-subsistence farms the agricultural sustainability if low, close to the satisfying level (0.5). In these farms all the aspects of agricultural sustainability have low levels, in comparison to the large and market oriented farms, as the economic (0.49) and social (0.45) sustainability are satisfying. There is a trend to decrease of the levels of integral, economic and social sustainability with the decrease of the farm sizes. The ecological sustainability of farms with small and medium sizes has the same levels, which are lower than of the bigger farms, but higher than the levels of subsistence farms.

Conclusions

This first of its kind assessment on sustainability of agro-ecosystems in Bulgaria let us make some important conclusions about the state of their sustainability, and recommendations for improvement of managerial and assessment practices. Elaborated and experimented holistic framework gives a possibility to improve general and aspects sustainability assessment. This novel approach has to be further discussed, experimented, improved and adapted to the specific conditions and evolution of agro-ecosystems of different types as well as the needs of decision-makers at various levels.

There is a considerable differentiation in the level of integral and aspects sustainability in agricultural ecosystems of analyzed generic and specific types. There are also big differences in the contribution to sustainability of agro-ecosystems of various sub-sectors of agriculture and farms of different juridical type and size. Individual indicators with the highest and lowest values show (critical) factors enhancing and deterring particular or overall sustainability of evaluated agro-ecosystem. Results on the integral agrarian sustainability level of this study based on the micro agro-ecosystem (farm) data are similar to the previous assessment based on the aggregate sectoral (statistical, etc.) data.

Having in mind the importance of holistic assessments of this kind for improving agrarian sustainability, farm management and agrarian policies, they are to be expended and their precision and representation increased. The latter requires a closer cooperation between and participation of all interested parties as well as improvement of the precision through enlargement of surveyed farms, and incorporating more objective data from field tests and surveys, statistics, expertise of professionals in the area, etc.

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