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EVALUATION OF AGRICULTURE SUSTAINABLE DEVELOPMENT

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Abstract

The paper presents the methodology to assess sustainable development in agriculture. First basic principles of sustainable development concept are presented. Main features of agriculture sustainable development were defined, by its specific areas. According to them, agriculture sustainable development indicators from Food and Agriculture Organization of the United Nations database were chosen and modified. By using mathematical metric and standardization methods, the algorithm was constructed, which allows to evaluate the current level of national agriculture sustainable development, by calculating rating for each sphere of sustainable development and for all spheres at ones. Presented algorithm is tested on database of Food and Agriculture Organization of the United Nations. At the end, results are presented. Dynamics chart of calculated rating is presented with box-whisker plot of world rating distribution. Specified Russian dynamics of agriculture level of sustainable development and rank place in global agriculture, according to the main domains concept of sustainable development.

Keywords: Agriculture, indicators, metric methods, Russia, sustainability, sustainable development.

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1. Introduction

Agriculture is a vital industry for every country. Moreover, agriculture alows to achieve one of the main goals of sustainable development “Zero Hunger” (Hák, Janoušková, & Moldan, 2016; Barbier & Burgess, 2017). This is why sustainable development of agriculture is so important.

Many studies are dedicated to the sustainable development of agriculture (Jeníček, 2013; Madu & Kuei, 2012; Martinet, 2011). They define basic of agriculture sustainable development in three main areas:

- Economic;
- Social;
- Ecological.

The economic area of agriculture sustainable development implies the optimal use of limited resources, i.e. achieving economic viability by maximizing revenue while minimizing costs.

The social area of agriculture sustainable development is expressed in its main social function, namely, in providing people with food in the quantities necessary to meet their needs.

The ecological area of agriculture sustainable development ensures the integrity of biological and physical natural systems in the production activities of agriculture (Glazovsky & Sdasyuk, 2005; Gnezdova et al., 2016; Gur'eva, 2016; Ugol'nickij, 2016; Ushakova, 2015).

2. Problem Statement

Nowadays when many countries try to reach the goals of sustainable development, agriculture gets one of the main positions in achieving them. This is why it is valuable to find out the current level of sustainable development before finding the best development pattern of agriculture.

3. Research Questions

The main questions of the research are below:

3.1. What are the trends of world agriculture sustainable development?

3.2. What is Russia’s position in world agriculture development?

4. Purpose of the Study

The paper aims at developing an algorithm, with the help of mathematical methods, that allows to evaluate national level of sustainable development in agriculture.

5. Research Methods

Summarizing international experience in evaluating the level of sustainable development, two approaches can be distinguished (Heink & Kowarik, 2010; Muthu, 2019; Sakalauskas, 2010; Danilov-Danil'yan & Losev, 2000; Bobylev, Zubarevich, Solov'eva, & Vlasov, 2008; Waas et al., 2014) :

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- the construction of an integral, aggregated indicator based on the degree of sustainability can be defined. Aggregation is usually based on three groups of indicators: economic, social and ecological ones;
- working out the system of indicators, each reflecting three areas of sustainable development.

The first approach was used in this study.

Research database

The main source of indicators was a database of Food and Agriculture Organization of the United Nations (FAO). Indicators were divided into three groups by domains of sustainable development:

- Economic;
- Social;
- Ecological.

Main indicators presented by FAO were modified into the following ones (Table 01).

Table 01. Indicators of agriculture sustainable development

#	Indicator	Elements (units)	Ideal value
Economic			
1	Gross Production Value per 1 employer in agriculture	constant 2004-2006 1000 I$ per capita	MAX
2	Government expenditure per Gross Production Value	value US$, 2005 prices per constant 2004-2006 1000 I$	MAX
3	Net Production Value per 1 employer in agriculture	constant 2004-2006 1000 I$ per capita	MAX
4	Production Value Added per 1 employer in agriculture	constant 2004-2006 1000 I$ per capita	MAX
Social			
5	Average dietary energy supply adequacy (3-year average)	percentage	MAX
6	Average protein supply (3-year average)	g/cap/day	MAX
7	Average supply of protein of animal origin (3-year average)	g/cap/day	MAX
8	Food production per 1 employer in agriculture	constant 2004-2006 1000 I$ per capita	MAX
Ecology			
9	Emissions (CO2eq) of Agriculture Total per Gross Production Value	Gg per constant 2004-2006 1000 I$	0
10	Share of Agricultural area	percentage	0

Indicators from FAO database are presented for different periods of time. Using moving average, indicators were evaluated for identical time periods. However, some indicators presented in FAO database have significant lag (Table 02).

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Table 02. Numbers of countries by time periods

Time periods	Number of countries
2001-2003	21
2002-2004	25
2003-2005	28
2004-2006	30
2005-2007	30
2006-2008	30
2007-2009	27
2008-2010	27
2009-2011	28
2010-2012	29
2011-2013	25

Algorithm

The rating was evaluated with metric methods calculating distance from the ideal object (country). A country that has ideal indicators value was referred to as an ideal country. The distance was calculated for each country from the ideal country for all time periods. The algorithm is presented in Figure 01.

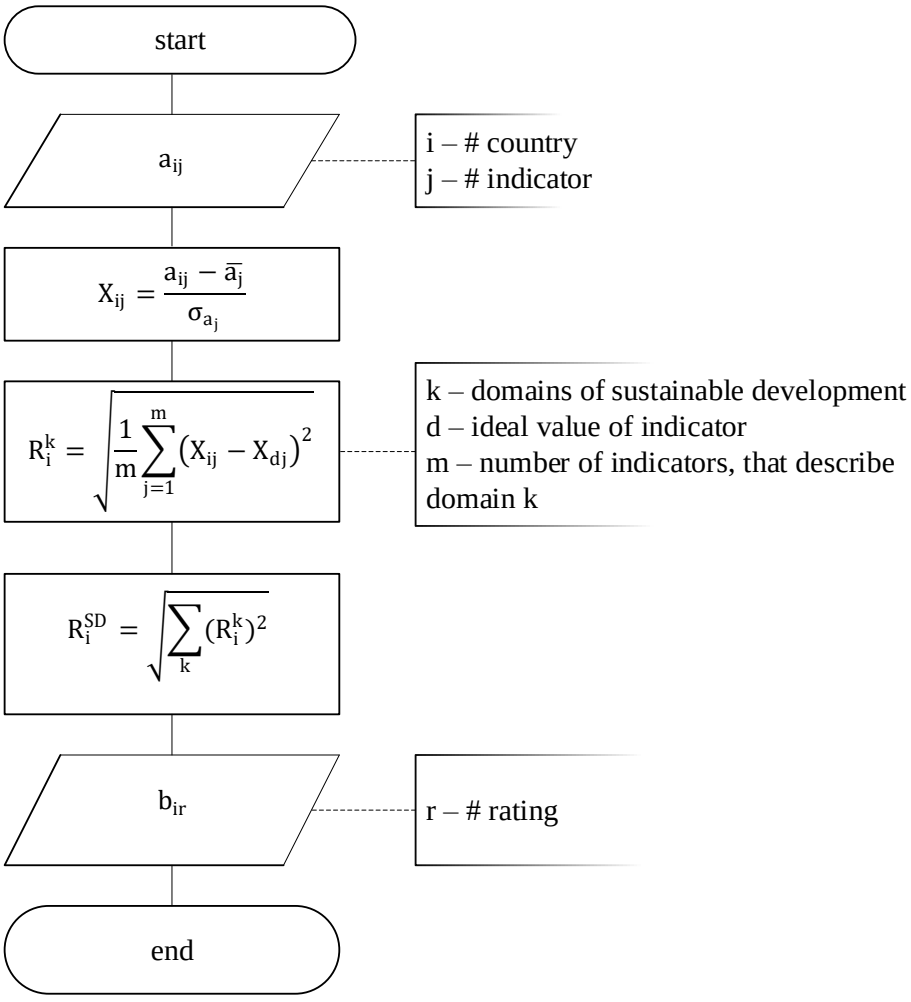

Figure 01. The algorithm of elevation country's level agriculture sustainable development

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Before applying the algorithm, some indicators (see Table 02) were modified. Indicators that have ideal value as "MAX" were inverted, so they will have number of ideal value, because $\lim_{x\to+\infty}\frac{1}{x}\to 0$.

The algorithm was produced in the following sequence:

- Indicators values (aij) were standardized.
- For each country rating (R_i^k) was calculated, by each sustainable development area.
- For each country rating (R_i^{SD}) was calculated.
- Countries were ranked by rating (R_i^{SD}).

The lower value of (R_i^{SD}) the higher level of agriculture sustainable development.

6. Findings

The algorithm was applied to every country that has information for those time periods (Table 03). Rating $\mathbf{R_i^{SD}}$ and $\mathbf{R_i^k}$ (with $\mathbf{k} \in \{\mathbf{En}, \mathbf{Sc}, \mathbf{En}\}$) were calculated**.**

Economic area

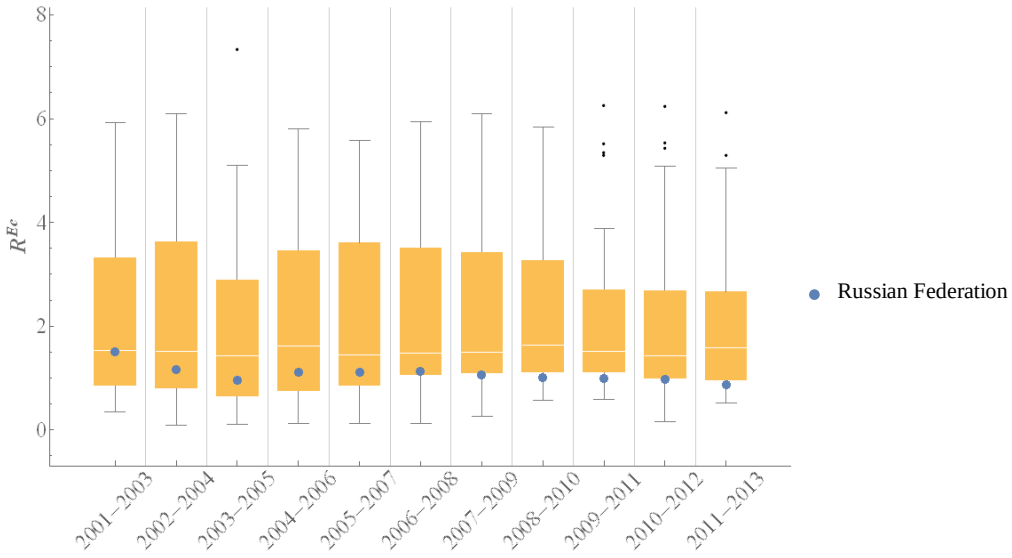

Figure 02. Box-and-whiskers diagrams of R_i^{Ec}

For most of the time periods value of $\mathbf{R_i^{Ec}}$ for Russia was less then 50% of other countries. In the last periods of time (2007-2013) Russian value of $\mathbf{R_i^{Ec}}$ was going outside of the interquartile interval. For all time periods under analysis, $\mathbf{R_i^{Ec}}$ became smaller by 40% (Table 03). All these facts mean that level of Russian agriculture sustainable development in economic are is increasing.

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Table 03. Main characteristic of R_i^{Ec} in dynamics

Time periods	#	R_i^{Ec}	Baseline growth rate	Chain growth rate
2001-2003	11	1,452	-	-
2002-2004	11	1,124	77,394%	77,394%
2003-2005	10	0,931	64,139%	82,873%
2004-2006	11	1,058	72,828%	113,546%
2005-2007	10	1,059	72,899%	100,098%
2006-2008	9	1,101	75,823%	104,011%
2007-2009	7	1,046	72,055%	95,030%
2008-2010	6	1,002	68,987%	95,742%
2009-2011	6	0,990	68,199%	98,858%
2010-2012	8	0,978	67,317%	98,708%
2011-2013	7	0,870	59,896%	88,975%

Social area

In the context of social area, the median value of $\mathbf{R_i^{Sc}}$ is increasing. Most of all it means that food production is growing slower than people population in most countries.

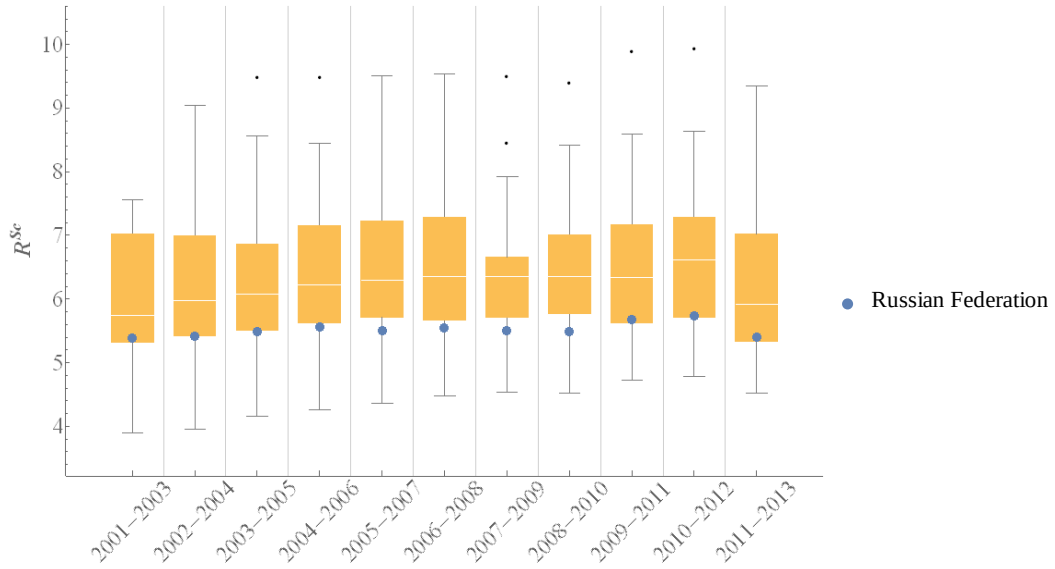

Figure 03. Box-and-whiskers diagrams of R_i^{Sc}

For most time periods value of $\mathbf{R_i^{Sc}}$ for Russia was less than 50% of the countries had. There was not so much of fluctuation of $\mathbf{R_i^{Sc}}$ over the past time periods. This fluctuation can also be viewed by the growth rate and rank number # (Table 04).

Table 04. Main characteristic of R_i^{Sc} in the dynamics

Time periods	#	R_i^{Sc}	Baseline growth rate	Chain growth rate
2001-2003	8	5,186	-	-
2002-2004	9	5,106	98,451%	98,451%
2003-2005	9	5,018	96,758%	98,281%

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2004-2006	9	5,251	101,248%	104,640%
2005-2007	7	5,210	100,455%	99,217%
2006-2008	8	5,232	100,898%	100,441%
2007-2009	7	5,258	101,395%	100,493%
2008-2010	5	5,223	100,710%	99,325%
2009-2011	9	5,400	104,130%	103,397%
2010-2012	9	5,454	105,165%	100,994%
2011-2013	9	5,166	99,615%	94,723%

Ecological area

Agriculture sustainable development had no dramatical change in ecological area. An exception has only 2 time periods (2009-2011 and 2010-2012), when the distribution of $\mathbf{R_i^{En}}$ changed by a much lower value. Russian dynamics of $\mathbf{R_i^{En}}$ doesn't differ strongly from world dynamics (Table 06 & Figure 06).

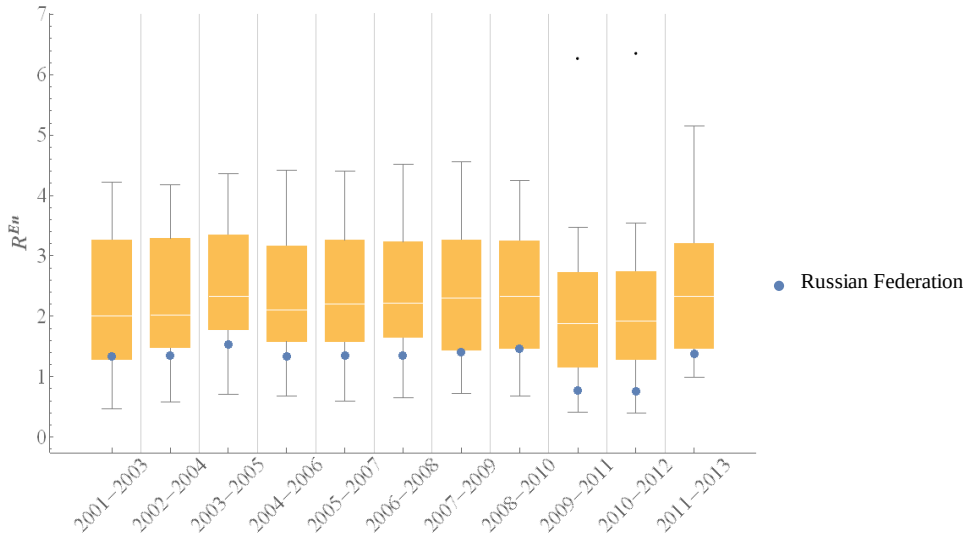

Figure 04. Box-and-whiskers diagrams of R_i^{En}

Table 05. Main characteristic of R_i^{En} in the dynamics

Time periods	#	$\mathbf{R_i^{En}}$	Baseline growth rate	Chain growth rate
2001-2003	6	1,305	-	-
2002-2004	6	1,302	99,811%	99,811%
2003-2005	6	1,487	114,002%	114,218%
2004-2006	4	1,268	97,238%	85,295%
2005-2007	4	1,299	99,610%	102,439%
2006-2008	4	1,311	100,476%	100,870%
2007-2009	4	1,414	108,416%	107,902%
2008-2010	4	1,475	113,060%	104,283%
2009-2011	5	0,762	58,394%	51,649%
2010-2012	5	0,753	57,719%	98,844%
2011-2013	5	1,374	105,295%	182,427%

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Sustainable development

Considering all three domains of sustainable development $\mathbf{R_i^{SD}}$ was calculated. In first time periods median value of $\mathbf{R_i^{SD}}$ was near to 3-rd quartile, then to the first one. That fact means there were more countries were concentrated then in the last periods of time periods.

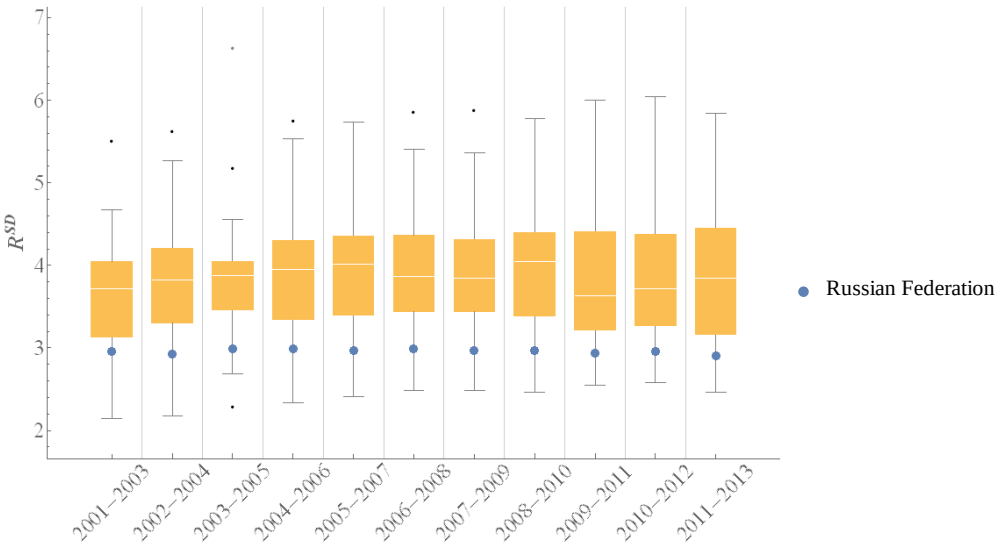

Figure 05. Box-and-whiskers diagrams of R_i^{SD}

According to all time periods, Russian level of agriculture sustainable development was high. Russian level of $\mathbf{R_i^{SD}}$ was lower then the first quartile, it mean that Russia was in 25% of countries with hightes level of agriculture sustainadble development. That fact also comfirms with dynamics of growth rate and rank number # in table 07. The rank number of Russian changed from 11 to 7.

Table 06. Main characteristic of R_i^{SD} in the dynamics

Time periods	#	$\mathbf{R_i^{SD}}$	Baseline growth rate	Chain growth rate
2001-2003	11	2,846	-	-
2002-2004	11	2,771	97,365%	97,365%
2003-2005	10	2,760	96,965%	99,590%
2004-2006	11	2,824	99,225%	102,330%
2005-2007	10	2,812	98,805%	99,578%
2006-2008	9	2,830	99,413%	100,615%
2007-2009	7	2,861	100,520%	101,114%
2008-2010	6	2,856	100,346%	99,827%
2009-2011	6	2,797	98,283%	97,944%
2010-2012	8	2,821	99,112%	100,844%
2011-2013	7	2,794	98,148%	99,028%

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7. Conclusion

Sustainable development of agriculture is impossible without an objective statistical evaluation of its current level of development. Presented methodology allows to estimate current level of sustainable development of agriculture in general and in the context of areas.

This methodology has some disadvantages. Because most of indicators has ideal values maximized (+∞), there is no much variation between countries by rating values.

Nevertheless, the results of presented methodology facilitate management decisions for countries agriculture sustainable development.

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