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THE EVALUATION OF INNOVATION IN AGRICULTURE. A META - ANALYTICAL STUDY OF LITERATURE

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Abstract

Innovation is a key driver of growth and development of the agricultural sector. The importance of innovation in agriculture is supported by the effects that innovation has on performance improvement of the economic entities in this field, in relation with efforts. Organization's decision to engage in innovation or to use the innovation results is influenced by the perception that the company has on net benefits generated by such an approach. The purpose of the paper is to highlight the evaluation way of innovation process from agriculture domain, through a meta-analytical study on literature published in the field. Results of the study show that, in literature, the general purpose of innovation in agriculture is to reduce environmental impact, followed by the purpose of decreasing costs.The main agricultural innovations studied by researchers are those of process which involve the decrease of resources consumption, such as technological innovations of soil conservation and the precision innovations.The evaluation of innovation process is done mainly through indicators that measures the level of increase in production, the level of cost reduction and through the decrease of negative effects on environmental.

Key words**:** *agriculture, innovation, meta-analysis*

INTRODUCTION

Agriculture is still the main supplier of food for population and an important supplier of raw material for other industries (textile industry, energy industry etc.). Regarding the attraction level of innovation in production processes, the agriculture domain is seen as a weak user of information and high technology [14].

The pressure of population growth and climate change boosts the innovative process from agriculture to find solutions for increasing the agricultural productions, for increasing the product quality and reducing the environmental impact. We note that the supreme goal of innovation in agriculture is one great, justifiable and which respond to humanity challenges. Intensification of farming determined the increase of average agricultural productions per hectare with 180% in 2000 year, compared to 1870 year, driven by an increase of only 20% of production factors [13]. According to Martin-Retortillo and Pinilla [10], the labor productivity in agriculture has increased threefold during 1970 - 2000 period, thanks to the use of chemical products, to the development of biological innovations (biotechnologies, genetic improvements etc.) and technological innovations (new agricultural technologies, innovation of machines and farm machinery etc.).

In the last 15 years, the farmers began to use in production activity the computer technologies and special software systems for accounting and the financial organization of work and for a more efficiently monitoring of it [4][7]. Increasing the efficiency of agricultural activities is based on the interaction of farmers with new technologies and their ability to position itself in a flow of information. In other words, the economic entities in the field must collect and use a large amount of information from numerous domains such as: meteorology, agricultural inputs industry, biotechnology industry, the domain of agricultural research etc. The conventional and superintensives farming practices can cause soil degradation, waters contamination, loss of biodiversity, the reduction of control on pests and diseases and, finally, reducing of agricultural product quality and of safety for consumers's health

[6] [1]. A challenge of research in agricultural domain is represented by the protection of consumer health by providing some healthy agricultural products, without pesticide residues and with a richer nutritional value [17].

Knowing the fact that, in the economy, the company is the economic actor whose primary function is the production, rests to these the main role in the implementation of innovations and in achieving of sustainable development goals, undertaken by nations.

More specifically, the economic entities from agriculture must adapt their production technologies to the requirements of environmental protection and human health and, at the same time, to register economic efficiency. In these conditions, it becomes important the motivation of the agricultural enterprise in adopting innovations, respectively awareness of the benefits that it will get as a result of innovation. Previous researches have highlighted the importance of identifying net benefits brought by innovation for increasing the company`s performances, arguing in favor of the innovation in economic processes [15][12]. As the innovation process involves a chain of steps (from idea generation to implementation of innovations and obtaining benefits) and a complex system of participants (researchers, suppliers, businesses, consumers), its assessment involves choosing the most suitable areas for measurement and also for the optimal indicators of quantifying [3].

The innovation process has an predominantly qualitative character, difficult to quantify in money, with a high complexity. Due to this fact, the evaluation of innovative process and its impact on enterprise performance is a challenge for researchers. Researchers have identified a direct relationship between innovation and organizational structure, enterprise culture and management practices [9][8]. Thus, entities which take the decision to innovate start to make changes at the organizational level (reorganization of staff, engaging in partnerships with research organizations etc.) and to make expenditures in an aggressive way, to create a favorable environment for creativity and innovation [9]. All these expenses involved by the engaging in innovation activities must be justified by increasing the performance level of the economic entity in agriculture [5][2]. In other words, the need to obtain the efficiency from innovation activities becomes particularly important to turn innovation into a continuous process at the level of economic entity, which insures the growth of market competitiveness.

The research purpose is to highlight the assessment approaches of innovation process from agriculture by seeking answers to the following questions:

• *Which is the innovation purpose in agriculture?*

• *Which are the main types of innovations in agriculture?*

• *Which are the indicators for assessing the innovation impact on performance of economic entities from agriculture?*

MATERIALS AND METHODS

In order to answer the research questions it was realised a meta-analysis of the specialized literature by aggregating a large number of information identified in the literature. The meta-analytical study has a critical qualitative and quantitative nature whereas will be identified, quantified and reported facts and conceptual approaches coming from previous publications of the researchers.

The meta-analysis consists in a organized application of an ensemble of criteria defined by researcher, for classifying, measuring and analyzing the material content [11].Through this approach were analyzed informations taken from a large number of studies from innovation domain in agriculture, informations which concern the applied methodology of research, the analyzed phenomena, the indicators for assessing the phenomena etc.

The importance of this research method is given by the possibility of in-depth knowing of the studying level of the research problem among scholars and the possibility of correlating of independent results obtained from the analyzed studies [16]. The data was processed using *IBM SPSS software functions - Version 20.*

From the methodological standpoint, the meta-analysis involved the following steps:
i) choosing of online international databases;
ii) selecting the areas of interest;
iii) establishing the level of analysis;
iv) selection of articles on phases;
v) grouping the analysis concepts;
vi) coding the identified analysis groups;
vii) data analysis.

RESULTS AND DISCUSSIONS

The performed analysis was aimed on identifying key concepts, measuring their frequency and the association relations between them and obtaining results that can be generalized, regarding the evaluation of innovation in agriculture. In this section are detailed the steps that have been taken to achieve the meta-analysis of studies in the field and the main results.

i) Choosing of online international databases

To select the articles from the area of interest of our research, we chose two international representative databases, respectively *Science Direct (SD)* and *Web of Science (WS)*.

ii) Selecting the areas of interest

Were chosen from each database, the areas shown in Table 1, which binds directly or indirectly to our research question (assessment of innovation in agriculture).

Table 1. Selected areas of interest

Science Direct areas	Web of Science areas
Agricultural and Biological Sciences	Agriculture
Biochemestry, Genetics and Molecular Biology	Meteorology Atmospheric Sciences
Business, Management and Accounting	Business Economics
Computer Science	Computer Science
Economics, Econometrics and Finance	Biotechnology Applied Microbiology
Environmental Sciences	Environmental Sciences Ecology

iii) Establishing the level of analysis

After identifying relevant research areas we have defined keywords for seeking the targeted articles. Thus, were applied for the *"abstract, title, key words"* the search criteria shown in Table 2.

Table 2. Defining the structure of search criteria

Science Direct	Web of Science
"innovation" and "agriculture" and ("measure" or "evaluate" or "asses" or "metrics")	TI=(agriculture or innovation) and TS=(agriculture) and AB=(measure or evaluate or asses or metrics)

Also, at this stage we chose as types of interest publications, the *"journals"*. The period of analysis was between 1990 and 2016. After applying the selection criteria described above, resulted 454 articles, structured as shown in Figure 1.

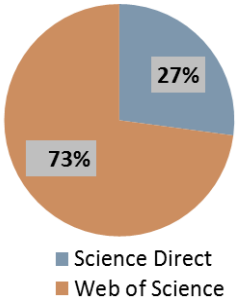

Fig. 1. Structure of identified articles, after determining the level of analysis

We note that, out of a total of 454 articles that met the search criteria, 73% of them are journls identified in Web of Science and 27% are journals identified in Science Direct.

iv) Selection of articles on phases

At the preliminary stage they were removed articles that were not available in *"full-paper"*, those that were duplicated in the two databases and those which were not written in English.

Table 3. Articles excluded in preliminary phase

Excluded articles	Database		
	SD	WS	Total
Total, of which:	**40**	**112**	**152**
- were not available in "full-paper"	35	64	99
- were not written in English	5	16	21
- were duplicated in the two databases	0	32	32

In drawing up the relevance of identified journals for our research, were excluded 81 articles after reading the abstracts and their`s titles (Table 4).

Table 4. Articles excluded by relevance

Excluded articles	Database		
	SD	WS	Total
Total, of which:	**20**	**61**	**81**
- excluded by title	11	23	34
- excluded by abstract	9	38	47

At the advanced selection of articles were excluded those articles that were rated with "NO" for at least two of the advanced quality criteria, according to Table 5. After the completion of the three-stage refining of the identified articles, in the analysis remained 74 articles, of which 34 articles were identified in Science Direct and 40 articles were identified in Web of Science. These articles represented the final studies used in analyzing the concepts related to evaluation of innovation in agriculture.

Table 5. Articles situation in advanced phase selection

Advanced selection criteria	Science Direct		Web of Science		Total	
	YES	NO	YES	NO	YES	NO
1. The article comprises at least one reason why it should be innovating in agriculture?	54	9	121	37	175	46
2. The article describes at least one type of innovation in vegetable agriculture?	42	21	102	56	144	77
3. The article describes at least one indicator for evaluating innovation in agriculture?	36	27	85	86	68	113
TOTAL SELECTED ARTICLES	**34**	**-**	**40**	**-**	**74**	**-**
TOTAL EXCLUDED ARTICLES	**-**	**29**	**-**	**118**	**-**	**147**

v) Grouping the analysis concepts

During this stage we have established the groups for analysis of the concepts that we want to identify (Table 6).

Table 6. Analysis groups

Group	Symbol	Group details
Innovation purpose	SI	The reasons for innovating in agriculture, both at macroeconomic and microeconomic level.
Process innovations	IPs	Innovations in agriculture that can be assigned to the innovation process (fundamental technological changes or new technologies and processes)
Product innovations	IPr	Innovations in agriculture that can be classified as product innovations (new or significantly improved characteristics).
Evaluation indicators	IE	Indicators through which has assessed the impact of the innovation process on the performance of economic entities in agriculture.

vi) Coding the identified analysis groups

For each analysis group were identified several concepts that have been described by key phrases found into the text of articles, expressing the same phenomenon. For the four groups of analysis were identified 19 representative concepts of characterizing innovation in agriculture, in terms of innovation objectives, the most studied types of innovations in agriculture and the indicators to assess the impact of the innovation on the performance of economic entities in agriculture.

The main identified dimensions were coded using numbers from 1 to 19. The detailed list of key expressions related to the 19 concepts, as they were identified in the articles, is presented in Appendix 1.

vii) Data analysis

The selected articles were described on the following qualitative criteria:

a) by publication year;
b) by methodology.

A percentage of 64.86% of selected articles were published in the last 5 years, which shows an increasing interest of researchers for studying the innovation issues in agriculture.

The trend of increasing the researchers`s interest for innovation in agriculture can be explained by the fact that the policies of states and supra-state organizations (the European Union, Food and Agriculture Organization of the United Nations, etc.) have the following priorities in the field of sustainable

agriculture: reducing resource consumption, increase food security and combating climate change.

Table 7. Coding the analysis groups

Group	Main concepts per group	Code	No. of articles in which the concept has been found
Innovation purpose	environment protection	SI1	21
	consumer protection	SI2	10
	decreasing the resources consumption	SI3	21
	increasing the farm performance	SI4	31
Process innovations	preserving technological innovations	IPs5	18
	precision technological innovations	IPs6	9
	crop organization innovations	IPs7	20
	innovations to reduce pollution	IPs8	21
	innovations for computerization of technology	IPs9	15
Product innovations	input innovations	IPr10	15
	genetic innovations	IPr11	8
Evaluation indicators	lowering costs	IE12	14
	production growth	IE13	17
	reducing the environmental impact	IE14	16
	productivities growth	IE15	14
	product quality growth	IE16	11
	strengthening of cooperation between farmers	IE17	10
	revenue growth	IE18	10
	copyright protection	IE19	3

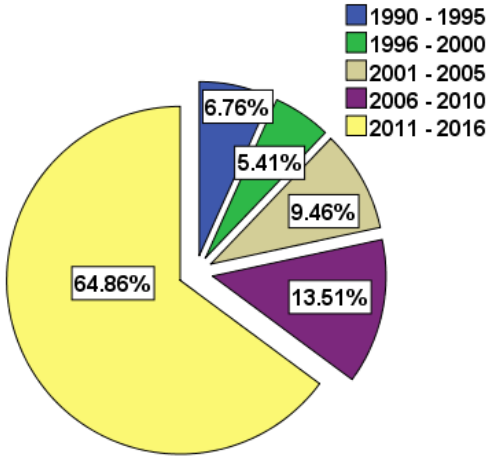

Fig. 2. Articles structure by publication year

In this regard, studies are needed to assess the impact of innovation activities on business performance, both at the economic and environmental level. Literature can provide important information for decision making in agriculture innovating and the researchers`s study results may be important elements for adapting national policies to the present economic realities.

Regarding the methodology used in the studies, have been identified the following categories of research methods used by the authors: sociological survey; case study; experiment; analysis of secondary data; others. Most of the analyzed articles fall into the categories: sociological survey (29.73%) and experiment (28.38%). Sociological surveys have mainly used tools such as questionnaire and interview, applied to farmers, researchers in the field and others actors.

Further we conducted a frequency analysis of key concepts and we have identified the following situations:

- the main goal of innovation in agriculture is to increase the performance (encountered in 41.89% of articles), followed by the environment protection and reducing the resource consumption, these having equal frequencies in 36.49% of articles;
- the most studied types of process innovations in agriculture are those aiming to reduce pollution (28.38% of articles), crop organization innovation (27.03% of articles)

and conservation innovation (24.32% of articles).

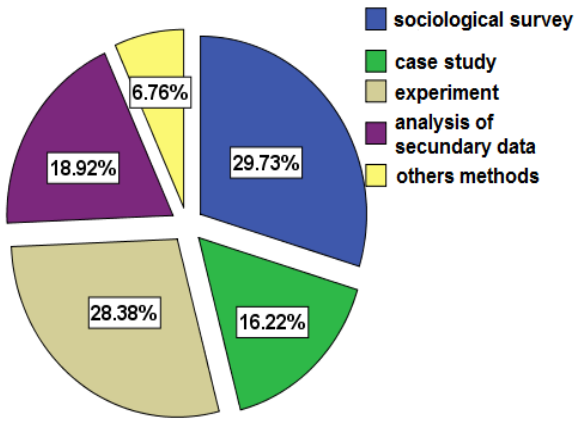

Fig. 3. Articles structure by methodology

These three categories of innovations presented in agriculture have a positive impact on the environment whereas
harnesses the natural potential of the area, helps to crop diversification and ensures the purpose of protecting the environment.
- in terms of product innovations, the highest frequency have the innovations on agricultural inputs (20.27% of articles), those containing new or significantly improved products ranging from pesticides, fertilizers, improvers etc.;
- assessing the effect of agricultural innovations is achieved in particular by measuring the increase in agricultural production (22.97% of articles) and quantify the reduction of environmental impact (21.62% of articles);
- the innovation evaluating indicator represented by copyright protection has the lowest frequency, being present in just 4.05% of articles. In agriculture, the majority of process innovations are being constructed on the existing knowledge or permanently generated in the organization, and obtaining copyright for such processes is very difficult to achieve [12].
The association relationship between qualitative variables was performed using the *multiple correspondence analysis* (MCA). Multiple correspondence analysis is an extension of correspondence analysis which allows to analyze the association relationship between several categorical variables.

Table 8. Model summary of MCA

Dimension	Cronbach's Alpha	Variance Accounted For		
		Total (Eigenvalue)	Inertia	% of Variance
1	.727	3.215	.169	16.919
2	.496	1.887	.099	9.934
Total		5.102	.269	
Mean	.642[a]	2.551	.134	13.427

To reflect the consistency of the chosen scale, the setpoint for *Cronbach's alpha* reliability coefficient should be as close to 1, and a limit of 0.7 is considered consistent for most researchers. Cronbach`s alpha coefficient has a value of 0.727 for the first dimension, which demonstrates the consistency and relevance of the chosen scale.
The two factorial axes explaine 26.9% of the total variance, and the first factorial axis explains 16.9% of variance, hence there are no big differences in the two axes.
By analyzing the correlation between the presence of the indicator *"increased performance"* and other indicators, we note the following:
- studies that assigns to innovation in agriculture, the role of improving the performance, included in the analysis the following indicators: strengthening of cooperation between farmers; revenue growth; lowering costs; production growth;
- studies that have not examined the role of innovation for *"increased performance",* included in the analysis the following indicators: innovations to reduce pollution; innovations for computerization of technology; preserving technological innovations.
The analysis of the association between indicators shows that the articles which presented as purpose of agricultural innovation, the environmental protection and resource consumption decrease, have evaluated the innovation through cost reduction and revenue increase.

CONCLUSIONS

The meta-analysis involved an exploratory conceptual analysis, to provide basic information necessary to conduct a future

empirical study at the level of economic entities in Romanian agriculture. Findings from systematic review of the literature can be summarized as follows:

i) researchers appeals mainly to sociological surveys and experiments to achieve their research regarding the innovation in agriculture;

ii) the main purpose of innovation in agriculture is seen as a response to climate change, that is to reduce the environmental impact;

iii) the most studied innovations are the process innovations that involve reducing the consumption of resources (preserving technological innovations, precision technological innovations, innovations to reduce pollution);

iv) the innovation is assessed in particular by reducing environmental impacts, increasing production and lowering costs.

The number of publications concering the assessment of innovation process in agriculture is increasing, as shown by the share of over 60% articles published after 2010. This shows the importance of the subject for researchers seeking to highlight or identify the effects of innovation in agriculture, on increasing performance at microeconomic and macroeconomic level.

Measuring the effects of innovation on performance in agriculture requires a complex and difficult to achieve process, given that most innovations in this field are based on existing knowledge or are created incidentally among the agricultural entities.

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APPENDIX 1

Detailed list of key expressions found in the articles

Group	Main concepts per group	Key expressions
Innovation purpose	environment protection	"pollution reduction" "reduce environmental impact" "improve environmental" "less environmentally damaging" "optimizing the environmental" "sustainable intensification" "improved environmental outcomes"
	consumer protection	"consumer protection" "consumer health" "a number of health benefits" "guidance on healthy and safe food products" "increases in food security"
	decreasing the resources consumption	"decrease of energy consumption" "fewer chemical inputs" "reduction in fuel" "labour costs were decreased"
	increasing the farm performance	"income growth" "performance growth" "increase farm wealth" "raise richness" "develop performance"
Process innovations	preserving technological innovations	"bio-mulch to conserve soil" "agri-environment conservation" "conservation agriculture practices" "aggradation-conservation agriculture" "controlled traffic farming" "no-till technologies" "minimum tillage"
	precision technological innovations	"institutional innovations" "targeted nutrient applications" "climate smart agriculture" "wireless sensor network technology" "GPS (global positioning system)" "husbandry GPS techniques" "physical and agrochemical mapping of lands"
	crop organization innovations	"production systems using georeferenced data" "crops in time (crop rotation)" "strip cropping" "cover crop cocktail" "crop diversification" "open pond algae agriculture"
	innovations to reduce pollution	"reducing gas emission practices" "greenhouse monitoring system" "Green Technological Foresight on Environmental Friendly Agriculture" "DMC systems for reduce risk of groundwater pollution"
	innovations for computerization of technology	"robot innovation" "ICT monitoring" "monitoring by sensors productions" "GPS mapping systems"
Product innovations	input innovations	"input-using innovations" "new fertilizer and pesticides" " biochemical new products"
	genetic innovations	"stress-avoiding innovations" "genetic resistance" "tolerance to pest, disease, or water stress" "biology plant technologies" "plant breeding"
Evaluation indicators	lowering costs	"reduction in fertiliser usage" "reduced fuel use" " increase resource efficiency " "efficient water consumption" "increasing the average yield" "reducing the costs with non-quality" "lower operating costs" "marginal cost of developing new technologies" "capitalization the natural potential" "reducing costs through minimum works"
	production growth	"increase in agricultural production"

		"increasing the output" "to intensify production" "allowing the farmers to increase the production" "enhance crop production" "increased food production" "seeking to improve production"
	reducing the environmental impact	"reductions in losses of all pollutants" "microbiological activity growth" "decrease in compacting of land" "carbon footprint reduction" "reducing energy consumption" "reduction of erosion" "landscape improvement" "reducing of greenhouse gases" "reducing of food waste" "reducing CO2 emissions"
	productivities growth	"increase profit" "gross margin growth" "improving labor productivity" "increasing agricultural productivity" "competitive prices" "price premium increase" "slightly higher price received" "overall increase in profitability" "farm profit increases" "increasing the profitability of cropping relative" "an increase in land productivity" "sustainably increasing agricultural productivity"
	product quality growth	"organic production growth" "development of quality feed" "quality organic products" "reducing of epidemics" "implementation of quality standards" "increased crude protein content in feed" "number of genetically modified hybrids" "number of improved plant" " improved quality of nutrition"
	strengthening of cooperation between farmers	"urban public involvement in agricultural networks" "development of urban agricultural innovation networks" "increasing education" "increasing communication to farmers" "linking farmers to innovation networks" "research – development expenditure outsourced"
	revenue growth	"increases the net household income" "income growth" "overall net income increased noticeably" "increases of maize grain sales" "signifycantly higher income stream" "rising real incomes" "maximizing yearly net income" "improve net household income and income stability" "improvement per unit of income" "income-related indicators have improved" "increases crop sale revenues" "improvements in grain sales"
	copyright protection	"new patents public owners" "new patents private owners" "patents renewed" "lifetime of patents"