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Are Yam Farmers Aware and Willing to Adopt the Aeroponics Farming System in Oyo State, Nigeria?

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Abstract

Despite the immense returns of new agricultural technologies to increase agricultural productivity and meet rising food demand, there is a lag in the adoption of these technologies by farmers. The aeroponics system is one of such innovative technologies implemented for seed yam propagation. This study assessed the awareness and the determinants of the willingness of yam farmers to adopt the aeroponics farming system, employing the likert scale and the logit regression model. Results showed that more than three-fifths of the farmers had never heard of the aeroponics farming system but were willing to adopt it for yam and seed yam propagation, although high cost of capital required for adoption was a major constraint. Key determinants of farmers' awareness of the aeroponics system include gender, age, education, membership of cooperative society, monthly income and access to extension agent, while the main factors influencing its adoption were marital status, age, access to credit, membership of cooperative society, farm size and income. Efforts at dissemination of aeroponics farming system for increased productivity should be intensified for its effective adoption by the farmers.

Keywords

The aeroponics system, yam farmers, awareness, perception, willingness to adopt.

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Introduction

Yam (*Dioscorea spp.*) is a major staple predominantly produced and consumed in West and Central Africa. Yams are multi-species crops with over 600 species, out of which six are socially and economically important for food, income, medicine and socio-cultural practices (IITA, 2009). Some of the edible yam species are water yam (*Dioscorea alata*), white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayanensis*), Chinese yam (*Dioscorea polystachya*) and three-leaf yams (Awoniyi and Omonona, 2006). In terms of production, Nigeria is the largest producer of yam in the world followed by Ghana, Cote D’Ivoire, Benin, Togo and Cameroon (FAO, 2013). As a major staple food, yam plays an important role in the nutrition of millions of people in the world regardless of the form (Umar et al., 2016). Economically, yam is important in local commerce in Nigeria and accounts for about 32% of farm income (Chukwu and Ikwelle, 2000). It also serves as a major source of foreign exchange earnings as it is used as a raw material in starch industries and pharmaceutical companies. Furthermore, the agricultural value chain of yam offers vast employment opportunities for millions of Nigerians (Verter and Becvarova, 2014). Therefore, producing large quantities of high quality mini tubers at minimal cost is essential for an economically viable supply of yam seed. This is important not only to maintain a steady supply of yam and yam seed, improve food security and increase foreign exchange earnings, but also to improve food performance of yam particularly in the face of climate change (Aighewi et al., 2015). Climate change is the primary determinant of agricultural productivity which is expected to influence yam production, hydrologic balances, input supplies and other components of agricultural systems. This situation deepens the challenges in agriculture, thus making agricultural and food systems unsustainable as well as hunger and poverty eradication a far-ending global objective. Hence, addressing

the issues of staple food production should be paramount as studies revealed that by 2050, the world population is expected to surpass ten billion mark, 34% higher than the current world population with much of the population increase occurring in developing nations (Cohen, 2003). However, the sustainable growth of the agricultural sector critically depends on the adoption of improved, scale-appropriate and ecofriendly technologies, implying that the role of adoption of new technologies in agriculture is fundamental to agricultural growth (Mottaleb, 2018).

Yam production in Nigeria is substantially low and cannot meet the growing demand at its present level of use. This can be attributed to some major challenges such as weed pressure, decline in soil fertility due to nutrient depletion by leaching, and the usage of traditional technology for the production of yam seed (Manyong et al., 2001). This situation is exacerbated by low multiplication rate of yam seeds, which is worsened by its long growth cycle and dormancy period. The low rate of multiplication of yam seeds and the use of edible tubers (25% - 30% of those planted in the previous planting season) for propagation make yam seedlings very expensive (Katung et al., 2006). This results in the use of mixed genotypes, pre-infected seed yam and farmlands, thus causing a build-up of an array of fungal, nematode, bacterial and diseases and pests which results to about 50% - 90% yield reduction. The provision of fresh and clean yam supply for the fast-growing population using traditional farming methods may remain insufficient. Hence, the need for a comprehensive and sufficient viable alternative such as the hydroponics and aeroponics system.

The International Union of Soil-Less Culture defines aeroponics as a system where roots are grown continuously or discontinuously in an environment saturated with fine drops (a mist or aerosol) of nutrient solution. Aeroponics is the science of plant cultivation without incorporation of the soil or a substrate culture. In aeroponics system, plants grow in the air with the assistance of an artificial support with no soil or substrate required to support the plant (Osvald et al., 2001). The system has shown promising returns in various countries and has been recommended as the most efficient, useful, significant, economical and convenient plant growing system than soil and other soil-less methods. The aeroponics system is one of the new technologies implemented for seed yam propagation through the project known as "Yam Improvement for Income and Food Security in West Africa (YIIFSWA) (Maroya et al., 2014). Unfortunately, many African nations, especially Nigeria, are lagging behind in the adoption and implementation of innovative technologies capable of turning the present situation around. This predicament is further worsened by the farmers' unlikely attitude to adopt innovations perceived to be of benefit.

Numerous studies on yam in Nigeria have laid emphasis on the production, demographics of farmers and farming households, as well as the present state, challenges and constraints facing the production of the crop. Studies have outlined several constraints facing the production of yam (Idumah et al., 2014; Verter and Bečvářová, 2015; Bassey 2017), as well as awareness, perception and willingness of farmers towards the use of innovation and technology in agricultural production (Oladele and Fawole, 2007; Edeogbon et al., 2008; Simtowe et al., 2012; Kolawole et al., 2012; Ochola et al., 2013; Mukadasi and Lusiba, 2016; Nain et al., 2017). However, there is a dearth of literature assessing the link between the awareness, perception and willingness of farmers towards the adoption of aeroponics system of yam production. Considering the foregoing, this paper will contribute to scarce literature on the awareness and willingness to adopt the aeroponics farming system by farmers. This study aims to assess the level of awareness of yam farmers and their willingness to adopt the aeroponic farming system, as well as the extent to which socioeconomic and other factors are associated with their perception and willingness to adopt the farming technology. Constraints to the adoption of the aeroponics farming system were also examined.

Materials and methods

The population for the study consisted of all yam farmers in the Local Government Area. The sample included 150 selected farmers using the Yamane (1967) formula at a 95% confidence level and ±5% precision. The selection procedure was a multistage sampling technique. The first stage was the purposive selection of Irepo Local Government Area (LGA) because of the prevalence of yam farmers in the LGA. In the second stage, five wards were randomly selected from the 10 wards in the LGA. The third stage involved the random

selection of 30 farmers each from the 5 wards which amounted to a total of 150 yam farming households. However, as a result of incomplete information, data from 133 respondents were used for analysis. A five-point Likert scale was used to assess the level of awareness and perception of the aeroponics farming system following the studies of Bagheri (2010), Ajibefun and Fatuase (2014) and Okoro and Ajieh (2015).

To examine the constraints encountered by yam farmers in the adoption of the aeroponic farming system, the mean of each constraint was determined by summing up the values picked by all the respondents, dividing by the total number of respondents and then ranking in order of magnitude. The awareness and willingness to adopt an innovation refers to a binary variable that takes 1 if the farmer is aware and willing to adopt the innovation and 0 if otherwise respectively. In this study, the binary variable defines the awareness and willingness to adopt the aeroponics farming system. The dependent variables: awareness or willingness to adopt are treated as 1 if the farmer *i* is aware or will adopt the aeroponics system and 0 if otherwise respectively. The binary logistic regression model, which studies the association between a categorical dependent variable and a set of independent (explanatory) variables, is appropriate given its computational simplicity and that awareness and the willingness to adopt fits into a dichotomous choice (Udimal et al., 2017 and Ntshangase et al., 2018). The model requires a binary dependent variable, independence of the observations and little or no multicollinearity among the independent variables. The model for this study is specified as follows:

$$Pi\,(Yi = 1) = Pi = F(Zi) = \\ = F(\alpha + \sum biXi) = \frac{1}{1+e^{-z}} \quad (1)$$

Where P_i is the probability that a farmer is aware of the aeroponic system and is willing to adopt the farming system respectively; X_i represents explanatory variables; and α and β are parameters to be estimated.

$$Prob(Yi = 0) = 1 - Prob(Yi = 1) = \\ = (1 - Pi) = \frac{1}{1+e^{z}} \quad (2)$$

From Equations (1) and (2), we get

$$\frac{\text{Prob(Yi = 1)}}{Prob(Yi = 0)} = \frac{Pi}{1-Pi} = e^{z} \quad (3)$$

Where P_i is the probability that Y_i takes the value 1 and then $(1 - P_i)$ is the probability that Y_i is 0 and e is the exponential constant. Equation 3 is the ratio of the probability that a respondent is aware or will adopt the aeroponics system to the probability that he is not aware or will not adopt the aeroponics farming system.

Therefore, taking the natural log of both sides of Equation (3), we get

$$Zi = In\left(\frac{Pi\,(Y_i=1}{1-Pi(Y_i=1}\right) = \log odds = \ logit\ Y = \\ = \beta_0 + \beta_1 X_1 + \ldots \quad \beta nXn \quad (3)$$

Where Y = dependent variable (awareness/ willingness to adopt); β_0 = intercept; $\beta_1 \ldots \beta_n$ = coefficients of the independent variables; $X_1, \ldots X_n$ = the independent variables.

Results and discussion

Table 1 presents the socioeconomic characteristics of the farmers. Nine out of ten of the farmers were males. Majority of the farmers were married and between the ages of 31 and 60 years with a mean age of 50.1 ± 12.4 years. A larger percentage of the respondents had one form of education or the other and were engaged in farming as their primary occupation with household sizes of between 6 and 10 persons per household respectively. The mean household size stood at about 11.0 ± 7.0 persons per household. About four-fifths of the respondents had no access to credit with more than two-fifths being members of one cooperative society or the other. Almost all the respondents had access to general agricultural information. The average farm size and farm size under cultivation of yam stood at 2.9 ± 1.0 and 2.1 ± 0.9 hectares respectively. Average monthly income was ₦58,500.00 ± ₦46,377.50 with more than three-fifths of the respondents having less than 20 years of farming experience. The mean years of farming experience of the respondents was 20.7 ± 15.2 years. The traditional system of farming was predominant in the study area with less than one percent indicating the use of the aeroponics farming system.

The level of awareness of respondents about the aeroponics farming system in the study area is presented in Table 2. The level of awareness of the yam farmers was obtained by summing up the values gotten from the responses; and deriving the mean score, standard deviation of each attribute was calculated and interpreted. The results revealed that the respondents' awareness about the aeroponics farming system was generally low as about seven out of ten respondents had

never heard of the aeroponics farming system. However, about one-tenths were aware but with little knowledge of the operations of the aeroponics system. Only 15.8% of the farmers showed adequate knowledge of the system.

Socioeconomic Characteristics	Frequency	Percentage	Mean	Standard Deviation
Gender				
Male	123	92.5		
Female	10	7.5		
Age(years)				
< 30	7	5.3	50.1	12.4
31-60	95	71.4		
>61	31	23.3		
Marital Status				
Single	4	3.0		
Married	123	92.5		
Widowed	4	3.0		
Divorced	2	1.5		
Educational Status				
No formal	38	28.6		
Primary	27	20.3		
Secondary	35	26.3		
Tertiary	33	24.8		
Primary Occupation				
Farming	133	85.0		
Trading	9	6.8		
Civil Servant	6	4.5		
Artisan	5	3.8		
Household Size				
1-5	39	29.3	11.3	6.8
6-10	43	32.3		
11-15	29	21.8		
>15	22	16.5		
Credit Access				
Yes	29	21.8		
No	104	78.2		
Cooperative Membership				
Yes	59	44.4		
No	74	55.6		
Access to Information				
Yes	128	96.2		
No	5	3.8		
Farm Size				
<1	12	9.0	2.9	1.0
1-4	40	30.1		
5-8	26	19.5		
>8	55	41.4		

Source: research findings

Table 1: Socioeconomic characteristics of respondents (to be continued).

Socioeconomic Characteristics	Frequency	Percentage	Mean	Standard Deviation
Yam Farm Size				
<1	32	24.1	2.1	0.9
1-4	70	52.6		
5-8	13	9.8		
>8	18	13.5		
Monthly Income (naira)				
<1000000	122	91.7	58500.00	46377.50
100001-200000	8	6.0		
>200001	3	2.3		
Farming Experience				
<20	82	61.7	20.7	15.2
21-40	29	21.8		
>41	22	16.5		
Farming System				
Aeroponics	1	0.8		
Soil based	132	99.2		

Source: research findings

Table 1: Socioeconomic characteristics of respondents (continuation).

Level of awareness	Frequency	Percentage
High	21	15.8
Medium	16	12.0
Low	96	72.2
Total	133	100.0

Source: research findings

Table 2: Level of awareness of the aeroponics farming system.

Information presented in Table 3 shows the respondents level of perception of the aeroponics farming system. Results revealed that majority of the respondents had a moderate to strong level of perception of the aeroponics system while only a minority of the respondents had a weak level of perception about the aeroponics system.

Category of Perception	Frequency	Percentage
Strong	34	25.6
Moderate	80	60.2
Weak	19	14.3
Total	133	100.0

Source: research findings

Table 3: Respondents level of perception of the aeroponics farming system.

The information on Table 4 shows the perception of the respondents towards several attributes of the farming system. The respondents perceived 9 statements in favour of the aeroponics farming system out of 12 statements used to ascertain their perceptions. The nine statements include: the system allows for increased yam and yam seedlings multiplication; the system requires less

Perception Attributes	SA		A		U		D		SD	
	F	%	F	%	F	%	F	%	F	%
The system helps control pest and diseases.	12	9.0	37	27.8	44	33.1	32	24.1	8	6.0
The system allows for increased yam and yam seedlings multiplication.	24	18.0	80	60.2	23	17.3	4	3.0	2	1.5
The system requires less use of land.	13	9.8	79	59.4	22	16.5	17	12.8	2	1.5
The system requires less use of labour.	6	4.5	63	47.4	39	29.3	23	17.3	2	1.5
The system is a usable technology.	11	8.3	93	69.9	22	16.5	7	5.3	0	0
The system has environmental benefits.	11	8.3	87	65.4	33	24.8	2	1.5	0	0
The system is affordable.	7	5.3	50	37.6	41	30.8	22	16.5	13	9.8
The system requires high cost of maintenance.	24	18.0	79	59.4	15	11.3	14	10.5	1	0.8
The system requires high technical know-how.	39	29.3	81	60.9	10	7.5	3	2.3	0	0
The system is highly complex.	8	6.0	41	30.8	27	20.3	57	42.9	0	0
The system ensures crops grow faster than any other system.	14	10.5	60	45.1	52	39.1	5	3.8	2	1.6
The system is stress free.	5	3.8	64	48.1	63	32.3	21	15.8	0	0

Source: research findings

Table 4: Perception of yam farmers about the aeroponics system.

use of land; the system requires less use of labour; the system is a usable technology; the system has environmental benefits; the system requires high cost of maintenance; the system requires high technical know-how; the system ensures crops grow faster than any other system; and the system is stress free. The remaining three statements were not favourably perceived by the respondents. These include: the system helps control pest and diseases; the system is affordable; and the system is highly complex.

The distribution of yam farmers by their willingness to adopt the aeroponics system as shown in Table 5 showed that seven out of ten respondents were willing to adopt the aeroponics system for yam and seed yam propagation despite earlier findings indicating a low level of awareness and a moderate level of perception. This indicates that apart from the availability of information, a farmer's decis ion/willingness to adopt is also influenced by other factors. These factors include: educational status, marital status, age of the farmer, farm size and access to credit, all of which can be grouped into three categories namely; economic, social and institutional factors.

Response	Frequency	Percentage
Yes	95	71.4
No	38	28.6
Total	133	100.0
Mean	1.29	
SD	0.45	

Source: research findings

Table 5: Willingness of yam farmers to adopt the aeroponics farming system.

The analysis of constraints faced by the yam farmers with respect to their willingness to adopt the aeroponics system revealed seven major constraints encountered by the farmers with respect to their willingness to adopt the aeroponics farming system as shown in Table 6. The mean of each constraint was determined by summing up the values picked by all the respondents and dividing by the total number of respondents. The most severe constraint faced by the respondents was high cost of capital required for adoption, followed by lack/inadequate information on aeroponics system and lack of access to credit facilities. On the other hand, the least severe constraints were the highly complex system and the tasking activities such as cleaning and spraying of nutrients involved in the aeroponics farming system.

Table 7 presents the results of the Logit regression analysis of the factors influencing the awareness of the yam farmers about the aeroponics farming system. The log-likelihood ratio following Greene (2011) was used to assess the overall significance of the model. The variance inflation factors (VIF) were used to inspect the level of multicollinearity between the independent variables. The Chi-square value of 29.90 and log likelihood value of -64.28 which are significant at 1% is an indication that the model is a good fit. The result shows that gender, age, educational status, cooperative value, income and access to extension agents were the explanatory variables that significantly affected farmers' awareness of the aeroponics farming system. Being a male farmer increased the likelihood of being aware of the aeroponics farming system

Constraints	Number	Mean	Rank
High cost of capital required for adoption	133	3.71	1
Lack / inadequate information on aeroponics system	133	3.41	2
Lack of access to credit facilities	133	3.07	3
The system requires technical know-how	133	2.36	4
Lack of governmental support	133	2.26	5
The system is highly complex	133	2.19	6
Activities involved in aeroponics system such as cleaning and spraying of nutrient is tasking.	133	1.60	7

Source: research findings

Table 6: Constraints faced in willingness to adopt the aeroponics farming system.

Explanatory variables	Coefficients	Marginal Effects	Z-value
Gender	0.0640**	0.0148	2.17
Age	0.8107***	0.2552	3.58
Marital status	-0.0366	-0.0070	-0.04
Household size	0.0023	0.0004	0.06
Years of education	-2.3231**	-0.1968	-2.22
Occupation	0.4857	0.0839	0.65
Access to credit	-0.3261	-0.0589	-0.49
Cooperative society	1.3129**	0.2068	2.34
Farm size	-0.0007	-0.0001	-0.03
Income	0.0000***	3.94e – 06	3.33
Extension agent	0.0917*	0.0116	1.85
Yam farming experience	0.0029	0.0005	0.13

Note: *, ** and *** indicate significant at 10%, 5% and 1% significance levels respectively

McFadden Pseudo R^2 = 0.19, Chi squared = 29.90, Log likelihood function = -64.28

Source: research findings

Table 7: logit model estimation results of factors influencing yam farmers awareness of the aeroponics farming system.

by 0.014 unit. This could be attributed to the fact that males have better access to information on innovative farming technologies relative to their female counterparts (Obisesan, 2014). Also, the age of the yam farmers had a positive and significant effect on awareness of the aeroponics system. This implies that a year increase in the age of a yam farmer will increase the likelihood of the farmer's being aware by 0.255 unit. This is contrary to apriori expectations as younger farmers are expected to be more progressive and interested in searching out new technologies. In addition, income had a positive and significant influence on awareness. Specifically, a naira increase in the monthly income of the farmers will result in a 0.0004 unit increase in the level of awareness of the farmers. Access to extension agent had a positive effect on awareness. This implies that having access to an extension agent increased the likelihood of being aware of the aeroponics farming system by 0.116 units. Extension agents play a major role in providing support services for delivering improved agricultural information to the farmers. Hence, this study shows the importance of extension officers and confirms the findings of Ajewole (2010) who emphasized the importance of information dissemination channels and the ability of the farmers to process and make use of such information. Conversely, an additional year of education of the farmers decreased the likelihood of being aware of the aeroponics farming system by 0.1968 units. This might not be unconnected to the fact that higher education confers on the farmers the ability to better acquire, process, and use information relevant to the farming system. This finding is consistent with the findings of Meena and Punjabi (2012). In addition, membership of a cooperative society decreased the probability of awareness of the aeroponics system by 0.207 unit. This could be attributed to the fact that farmers who are members of one cooperative organisation or the other would have access to information on innovations through

information disseminated in their respective cooperative organisations. This result corroborates the findings of Ilesanmi and Akinmusola (2016). Also, farmers in cooperative societies have more access to social capital enhancing trust, idea and information exchange (Mignouna et al., 2011).

The result of the logistic regression analysis of the factors influencing yam farmer's willingness to adopt the aeroponics farming system is presented in Table 8. The criterion used to assess the overall significance of the binary logit model was the log-likelihood ratio following Greene (2011). The variance inflation factors (VIF) were used to inspect the level of multicollinearity between the independent variables. The classification accuracy indicated the appropriateness of the model in predicting the adoption of the aeroponics farming system given the independent variables in question. A chi square value of 90.74 ($p< 0.01$) and log likelihood value of -33.86 thus indicate the goodness of fit of the model. Many of the explanatory variables have the expected signs and are statistically significant. Key positive determinants of farmers' willingness to adopt the aeroponics farming system include marital status, access to credit and extension agent, cooperative society, farm size, and income. However, the age of the yam farmer had negative effects. Marital status had a positive and significant effect on the willingness to adopt the aeroponics farming system. In other words, being married increased the likelihood of farmers' willingness to adopt the aeroponics system by 0.0115 unit. Married farmers are likely to have larger household sizes consisting of their wives and children who serve as a source of labour for activities in yam production (Okoffo et al., 2016). Also access to credit and membership of a cooperative society increased the log-likelihood of the willingness to adopt the aeroponics farming system by 0.0106 unit and 0.2662 unit respectively. Farmers with credit access are able to afford inputs required for the new technology. Also, credit can serve as a motivation towards adoption through the relaxation of rate of liquidity constraints as well as boosting of the farmer's risk bearing ability. This is in line with the findings of Ntshangase et al. (2018). In addition, the role of organizational membership in generating support for uptake of new innovation is that of information sharing and resource mobilization and higher market bargaining power (Ibitoye et al., 2013). Farm size was also positive implying that a hectare increase in farm size of farmers increased the likelihood of yam farmers' willingness to adopt the aeroponics farming system by 0.2865 unit. In other words, farmers with large farm sizes have the flexibility to adopt new technologies. This result corroborates the findings of Mignouna et al. (2011).

Furthermore, a positive and significant effect of monthly income on the willingness to adopt the aeroponics farming system implies that a naira increase in the income of farmers increased the likelihood that yam farmers would be willing to adopt the aeroponics system by 0.141 unit. This may be due to the fact that farmers with higher income would be able to buy inputs for farming and can afford new technologies (Ntshangase

Explanatory variables	Coefficients	Marginal Effects	Z-value
Gender	2.0447	0.3376	0.87
Age	-0.1037***	-0.0113	-2.83
Marital status	1.9382*	0.0115	1.89
Household size	0.0195	0.0018	0.36
Years of education	-1.0735	-0.1255	-1.01
Occupation	1.5352	0.2114	1.16
Access to credit	0.0599**	0.0106	2.37
Cooperative society	2.8839**	0.2662	2.28
Farm size	1.5970**	0.2865	2.57
Income	0.6313*	0.1416	1.86
Extension agent	1.7877**	0.0094	2.208
Yam farming experience	-0.10411	0.0570	1.11

Note: *, ** and *** indicate significant at 10%, 5% and 1% significance levels respectively

McFadden Pseudo $R^2 = 0.58$, Chi squared = 90.74, Log likelihood function = -33.86

Source: research findings

Table 8: logit model estimation results of factors influencing yam farmers willingness to adopt the aeroponics farming system.

et al., 2018). On the other hand, the age of the farmer had a negative and significant effect on the willingness to adopt the aeroponics system. This implies that a year increase in age decreased the likelihood of adopting the aeroponics farming system by 0.0112 unit. This may be owing to the fact that older farmers are accustomed to and prefer the traditional system of yam production, and as a result are reluctant to adopt new technologies. Younger farmers on the other hand are usually more educated, knowledgeable and willing to bear risks involved with adopting agricultural innovations. This finding corroborates the findings of Okoffo et al., (2016). Extension services create the platform for acquisition of the relevant information that promotes technology adoption (Nadeeshani Silva and Broekel, 2016). Contact with extension agent also increased the likelihood of farmers' willingness to adopt the aeroponics farming system by 0.94 unit.

Conclusion

A major interest of policy makers in less developed countries is increased agricultural productivity to meet the rising demand for food with increase in population size. Agricultural productivity could however be improved if it is recognized that a key determinant of growth in productivity is the technology employed by the farmers. Evidence from many developing countries including Nigeria however reveal a low level of awareness of innovative technologies, such as the aeroponics farming system, required for increased agricultural productivity compared to developed countries. Farmers either do not adopt these technologies outrightly or their adoption of it is slow. Farmers' perception of the appropriateness of such improved technologies has been shown to be key to the adoption of the technology. Thus, efforts at ensuring effective dissemination of these technologies for effective adoption by farmers should be intensified to achieve the desired results.

Yam farming in Nigeria has been faced with a lot of constraints particularly the problem of obtaining seed yam for the cultivation of yam. This has resulted in the continuous drop in the national yam production over the years causing high cost of production and the inability to meet the demand for the fast-growing population and export standards. Based on the foregoing, this article examined the level of awareness and willingness to adopt the aeroponics farming system by yam farmers and identified the constraints inhibiting the adoption of the farming system by the farmers.

The result of the level of awareness of the farmers obtained with a likert scale indicate that majority of the respondents had never heard of the aeroponics system, while only a few had adequate information and hence were fully aware about the system for yam cultivation. Furthermore, examining the perception of the respondents towards the aeroponic system revealed that about three-fifths of the respondents had a moderate perception about the system while only about one-quarter had a strong perception about the system. The respondents indicated that high cost of capital is the major constraint to the adoption of the aeroponic farming system by yam farmers, followed by lack of adequate information on the aeroponics farming system. While farmers' awareness of the aeroponics farming system was mainly influenced by gender, age, educational status, cooperative value, income and access to extension agents, factors influencing their willingness to adopt include marital status, age, access to credit, membership of cooperative society, farm size and income. This indicates that these factors should be the focus of development efforts for increased awareness and adoption of innovative technologies for improved agricultural productivity.

Based on the findings of this study, it is recommended that yam farmers be encouraged to organize themselves into groups, such as cooperative societies, while efforts at adequate farmer-extension contact should be intensified. This is to allow for quicker and easier dissemination of information pertaining to agricultural innovations and technologies most especially the benefits of adopting such new technologies and its positive effect on their productivity. The study identifies the constraints to adoption of a new agricultural technology despite the expected benefits from the adoption of it. Thus, efforts towards the availability and accessibility of credit facilities to farmers, most especially to small-scale farmers, to reduce the high cost of capital constraint encountered by the farmers, in the adoption of new technology should be a major policy thrust of government. The study showed that higher levels of education increased farmers' likelihood of awareness of the aeroponics farming system. In view of this, policy measures targeted towards improvement in human capital development of the farmers is key to the adoption of new technologies.

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Diamond Model and Competition of Rubber Export Markets: Evidence from Sumatra Economic Growth Center

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Abstract

The focus of this research is on how the position of competitiveness of Indonesian rubber exports among ASEAN countries and the dominant factors causing the competitiveness of Indonesian rubber exports experienced a downward. Approach to measuring rubber export competitiveness uses the Lafay Index, and factors that affect the competitiveness using the Diamond model by using panel data analysis method. The results show that there has been a decline in the competitiveness of Indonesia's rubber exports to ASEAN countries, the greatest decline in competitiveness that occurred in Singapore, Malaysia, and Thailand. Factors that affect Indonesia's export competitiveness that is more dominant are a foreign direct investment, price levels, and interest rates. FDI should be directed at improving the quality of export products following the quality of ISNR and upgrading the quality of rubber export products from SIT 20, and directly more beneficial for the manufacture of goods for final consumers.

JEL Classification: F14, O24, P33, Q17

Keywords

Export competitiveness, the Lafay index, diamond model.

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Introduction

Export competitiveness is one of the determining factors in the persistence of a country's long-term economic growth, especially the tendency in manufacturing exports, besides the degree of equality of income distribution, democratically managed institutions, trade openness, and foreign direct investment. (Porter, 1981; Grant, 1991; Snowdon and Stonehouse, 2006; Berg et al., 2012). Openness Foreign trade which is believed by economists as a very effective factor in maintaining long-term growth should rely on trade in agricultural products that have been processed and have led to agroindustry and agribusiness, so that they have higher added value. (Burianová and Belová, 2012; Shoufeng, et al., 2011). Trade-in agricultural products which are superior products such as rubber by the center of economic growth is a mainstay product that is expected to drive economic growth in the central region of economic growth in Sumatra. (Ansofino, 2016; Jambor et al., 2017, Ansofino and Zusmelia, 2017; Svatos, et al., 2018; Huo et al., 2019; Ansofino et al., 2019).

Calculation of the competitiveness of a country's exports so far has mainly focused on the index revealed comparative advantage (RCA), taking into account the export value of products exported with and the total export value of all commodities produced by a country. (Balasa and Noland, 1989; Ansofino and Zusmelia, 2018; Jambor et al., 2017). This RCA Index has been able to provide the position of export competitiveness of countries among other parts of the world (Vollrath, 1991; Sarker and Ratnasena, 2014; Bojnec and Ferto, 2014), such as the export competitiveness of agricultural products in Africa, Canada, and Europe. The use of the RCA index has even been combined with trade competitiveness indexes that are more specific to trade products such as coffee, rubber, and cocoa (Shoufeng, Feng and Jiao, 2011).

The concept of competitiveness has been used extensively, especially at the country, company, industry, and trade product levels (Bhawsar, 2015; Boonpattarakan, 2012; Qin and Pastory, 2012; Svatos et al., 2018; Zhang et al., 2010; Xue Liu,

2009). This study analyzes the competitiveness of the Indonesian state using product data Indonesia's rubber exports to ASEAN, and other countries. The study of competitiveness at the country level has been established in the monumental work of Porter 1990; Porter, 1981; Grant, 1991), by making data on exports and imports of major commodities as material for analysis. Trade competitiveness in the form of rubber exports uses the revealed comparative advantage index and uses a diamond model framework from Michael Porter with several modifications (Kamath et al., 2012), so that the diamond model from Michael Porter has rearranged the theory of regional and national competitiveness to the theory of locative competitiveness advantage (Kamath et al., 2012). There are four determinants of regional and national location competitiveness namely local demand conditions, factor condition, the presence of similar industrial competitors, and finally the company strategy that refers to the rules and incentives and norms that apply in the competition at the local level.

Determination of regional economic competitiveness, especially in producing cluster development, in this case, is the emergence of emerging markets, namely the economic corridor of Sumatra, of course also influenced by several determining factors for its success (locational success), namely demand conditions, factor conditions, democratic institutional support, knowledge spillover, technology transfer, economic agglomeration, increasing returns, public policy and the presence of social infrastructure and capital and the most important is the presence of creative groups (Kamath et al., 2012; Florida, 2012, Romer, 1990; Almeida and Kogut, 1999; Combes, et al, 2005; Billings and Johnson, 2016; Joas, 1996), all of which have become attributes of economic clusters or economic corridors and economic growth to be able to compete directed by this diamond factor.

The competitiveness of agricultural exports such as rubber has been traditional support for emerging markets in regional and global competition, the diamond model can provide an important basic framework in analyzing the competitiveness of rubber exports at the center of economic growth (emerging markets) of Sumatra and the ASEAN region in general. The interconnectedness of rubber economic resources in the Sumatra economic corridor can offer Indonesia's competitive advantage in the face of trade competition with ASEAN countries. The spatial effect of interconnecting rubber economic resources on the regional competition market can be analyzed with the Diamond model (Porter, 1981; Grant, 1991) with its development on the Lafay Index, (Huo, et al, 2019; Kamath et al., 2012). The main problem examined in this study is whether the rubber trade center of the Sumatra corridor has competitiveness in trade with the ASEAN region and globally? What factors influenced the increase in the competitiveness of rubber exports in the Sumatra economic corridor? how to increase the added value of the rubber economy and be able to capture its economic rent by rubber entrepreneurs in their hinterland areas?

Materials and methods

The measurement of rubber export competitiveness from the export growth centers of Sumatra's economic corridors uses the revealed comparative advantages (RCA) method (Balasa and Noland, 1989; Kamath et al., 2012; Qineti et al., 2009), and the Lafay Index (Svatos et al., 2018; Burianová and Belová, 2012; Zaghini, 2003), while the factors affecting power Sumatra's economic corridor rubber export competitiveness refers to the Diamond model pioneered by Porter (1990), and Grant (1991) and developed into the global economics management system (GEMS) by Kamath et al. (2012).

The RCA model used to calculate the competitiveness of rubber exports in the Sumatra economic corridor takes the following form:

$$RCA_j = \left(\frac{X_j - M_j}{X_j + M_j}\right) 100\,, \qquad (1)$$

where X_j and M_j are the value of exports and imports of agricultural products including rubber in the economic corridor area of Sumatra. To maintain the stability of the RCA index value, Balassa (1977) recommends using the RCA index in the form of a ratio too, namely:

$$RCA1_j = \left(\frac{X_j/M_j}{X/M}\right), \qquad (2)$$

where X_j and M_j are agricultural export values including rubber from the Sumatra economic corridor area, while X and M are the total export and import values of the agricultural sector trade in the Sumatra Economic Corridor region. Both of these models assess, if the RCA index is greater than one, then the rubber commodity analyzed is competitive, and vice versa, rubber commodity

with an RCA index of less than one becomes less competitive.

The limitations of the RCA index model are more likely to be appropriate for analyzing the competitiveness of exports in a country's trade with its partners, but must also consider global trade conditions or the global macroeconomic situation, so for this purpose, this study also uses the Lafay Index (Lafay, 1992; Dagenais and Muet, 1992) which takes the following form:

$$Lapay\ Index\ (LFI) = = \left(\frac{X_j^i - M_j^i}{X_j^i + M_j^i} - \frac{\sum_{j=1}^{N}(X_j^i - M_j^i)}{\sum_{j=1}^{N} X_j^i + M_j^i}\right)\frac{X_j^i + M_j^i}{\sum_{j=1}^{N} X_j^i + M_j^i}100 \quad (3)$$

Where X_{ij} and M_{ij} represent exports and imports of rubber products represented by country i up to the number of N countries. The LFI index consists of three elements namely:

$$LFI_1 = \frac{X_j^i - M_j^i}{X_j^i + M_j^i} \quad (4)$$

$$LFI_2 = \frac{\sum_{j=1}^{N}\left(X_j^i - M_j^i\right)}{\sum_{j=1}^{N}\left(X_j^i + M_j^i\right)} \quad (5)$$

$$LFI_3 = \frac{X_j^i + M_j^i}{\sum_{j=1}^{N}\left(X_j^i + M_j^i\right)} \quad (6)$$

So that $LFI = (LFI_1 - LFI_2)\ LFI_3\ x100$ (7)

LFI_1 measures net exports for certain commodities such as rubber with all exports in the agricultural sector, this is commonly measured in the Balassa RCA index model. LFI_2 compares the total net exports (the sum of all commodities) with the total trade in the agricultural sector, the value of LFI will be positive if $LFI_1 > LFI_2$, this is the RCA index of certain trade commodities with the sum of all traded commodities. LFI_3 is the share of a certain commodity against all the total trade of a country. The positive value of the LFI index indicates the existence of export competitiveness, whereas the negative value of the LFI index reflects the lack of competitiveness of export competitiveness.

Factors that affect the competitiveness of rubber exports in the corridor region of Sumatra refer to the diamond model in which five variables affect the competitiveness of these exports, namely: demand condition in the region (demand condition). According to Porter (1990) demand condition is measured by identifying (1) the size and composition of local demand, (2) the size and growth of local demand, (3) the number of local traders (local buyers) (Kamath et al., 2012). This study measures the demand condition of the growth of rubber imports and the number of rubber traders (local buyers), so that the growth of imports will reduce the competitiveness of imports, as well as the increasing number of rubber traders will make rubber competitiveness weaker, because most rubber traders have not made an increased value-added (processing) in trade (Ansofino, 2016; Ansofino and Zusmelia, 2018; Ansofino, et al., 2019; Ansofino, and Zusmelia, 2019). The data used was obtained from the world integrated trade solution (**https://wits.worldbank.org/**).

Factor conditions in the form of supply, production costs, labor productivity, technology, management, entrepreneur. This study uses data on the amount of rubber production produced by each country, and the amount of innovation and entrepreneurship produced by each country. Data were obtained from the Asian Development Bank (**https://data.adb.org/dataset/basic-statistics-asia-and-pacific**).

Factors in the presence of supporting industries such as industry partners, availability of logistics services, accounting, and legal services, financial and tax services, distribution services, and export services, including in this case innovation and use of technology (technological cluster), the creation of agglomeration of the rubber processing industry.

Factor firm, strategy, structure, and competitors (rivalry) as a form of ability and climate of local competitiveness, a macroeconomic climate, and a conducive political climate, a culture of innovation and local entrepreneurs. Factors that shape local competitiveness are also policies related to trade and investment openness, licensing rules, antitrust policies, the influence of corruption, (Kamath, et al., 2012), (Porter, 1981). It is expected that all of these variables can explain the level of competitiveness of Indonesia's rubber trade in ASEAN countries.

Results and discussion

Competitiveness of Indonesia's rubber exports with ASEAN countries

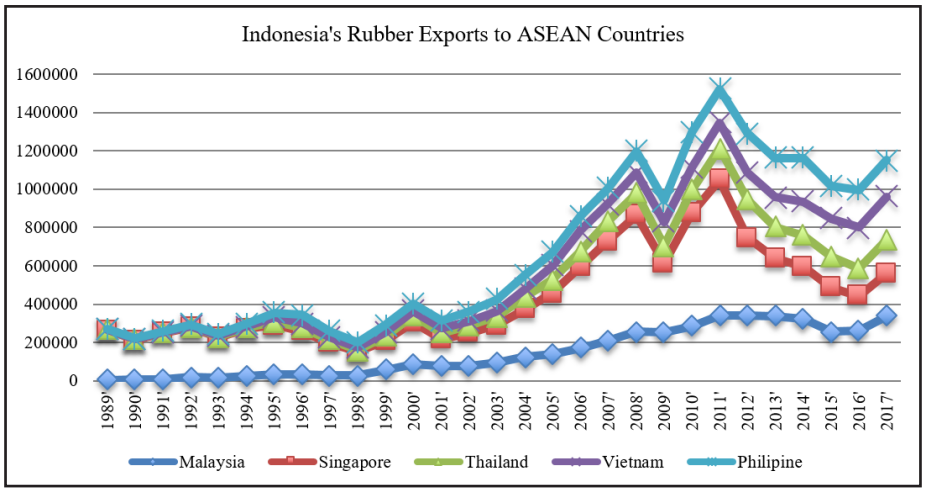
Indonesia's rubber exports to ASEAN countries as its main trading partners have continued to increase since three decades ago, especially since the boom in oil exports in the 1980s was replaced by a boom in crop exports in the 1990s until the end of 2011, the increase in exports was allegedly by increasing the amount oil palm and rubber smallholder farms (Euler et al., 2016;

Winoto and Siregar, 2008). Rubber and palm oil are trade commodities that are the mainstay of the economy of the Sumatra economic corridor. However, the added value of the rubber trade is still captured by the trade partners of ASEAN countries, specifically Singapore and Malaysia. (Ansofino and Zusmelia, 2018).

Figure 1 illustrates the increasing trend of Indonesia's rubber exports to ASEAN countries. There are at least three shocks that have decreased, namely the economic crisis events in 1998. The greater shocks that occurred in 2009 were more due to natural disasters; an earthquake in West Sumatra province as a center for rubber production in Indonesia. The recovery in the post-disaster rubber export increase reached its peak in 2011, and is slowly continuing to slowdown until now.

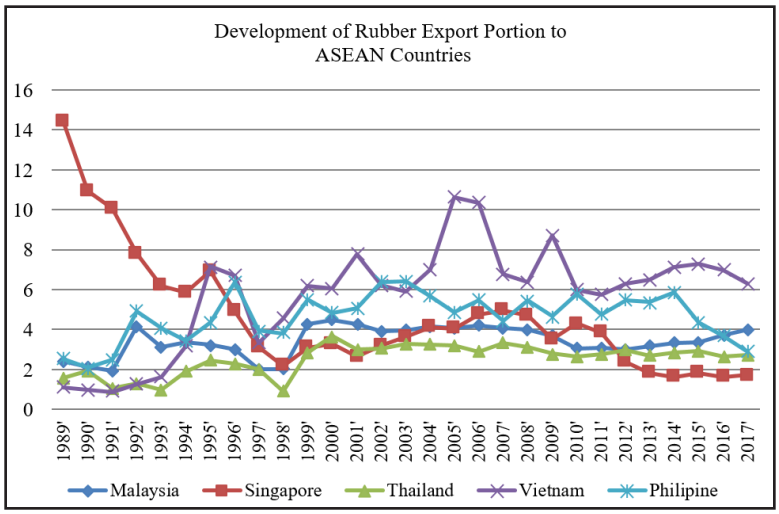
The main export destination countries for Indonesia's rubber and volume are Malaysia, Vietnam, Thailand, and Singapore. However, the State of Singapore has received the greatest increase in added value (Ansofino, et al, 2018), the trend has continued to decline over the past two decades. Even so, the percentage of rubber exports to ASEAN countries, when compared with total exports to the relevant countries, the trend continues to increase, especially to Vietnam, the Philippines, and Malaysia (see Figure 2). Two countries namely Singapore and Malaysia showed a share of rubber exports with a decrease in total exports.

Indications of the declining trend in the share of rubber exports to Singapore, and Thailand, reinforced by the decline in export competitiveness as indicated by its Lafay index figures which



Source: Own calculation based on data from the Wits World Bank, 2019

Figure 1: Development of Indonesia's rubber exports to ASEAN countries.



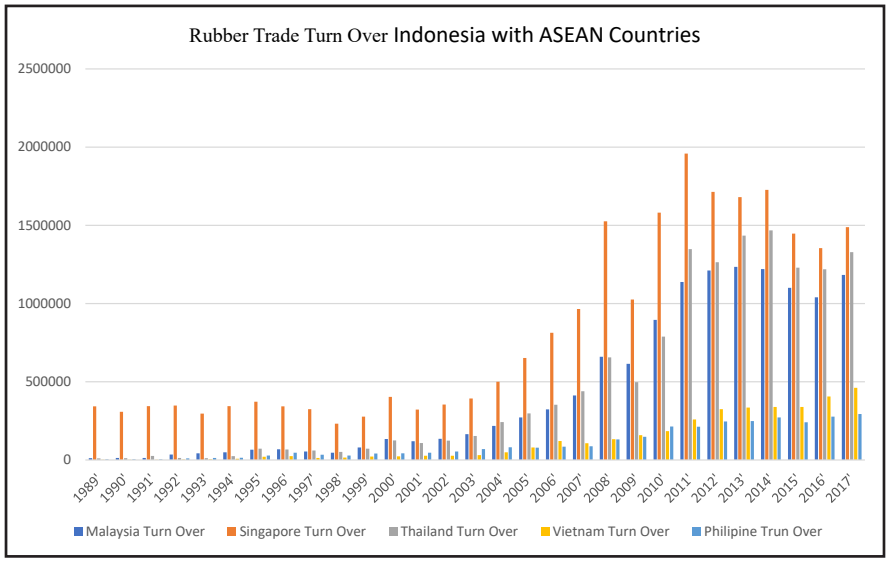
Source: Own calculation based on data from Wits World Bank, 2019

Figure 2: Development of rubber export portion to ASEAN countries.

have also declined since the economic crisis period in 1998 and experienced increasingly less competitive, in line with the increasing competitiveness of exports to Vietnam and the Philippines. Nonetheless, the total trade activities between Indonesia and ASEAN countries as indicated by the value of trade turnover, the trend is still increasing since the last two decades and is still dominated since the beginning with the countries of Singapore, Malaysia, and Thailand.

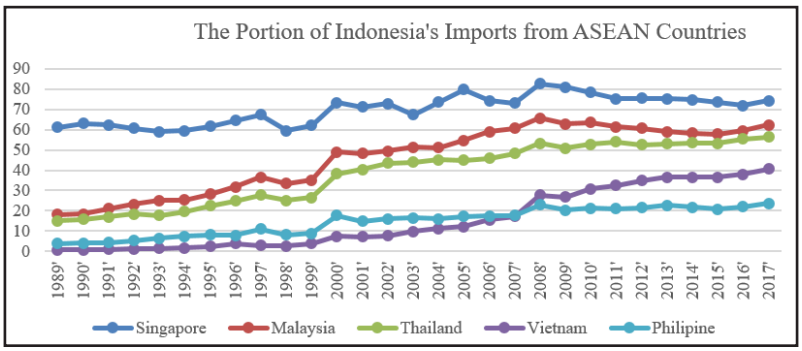
The increasing trend of Indonesia's trade activities with ASEAN countries is shown by the increasing value of turnover and is led by Singapore, Malaysia, and Thailand, (see Figure 3) but in these three countries, the Lafay Index value which measures the competitiveness of Indonesia's rubber exports experiences decrease (see Figure 4). The sharpest decline in the competitiveness of Indonesia's rubber exports was in Singapore, and Malaysia, and Thailand. However, in line with the declining competitiveness of Indonesia's rubber exports, the three ASEAN countries which have been the main trade partners, have been followed by the expansion, and increase of Indonesia's trade activities with the Philippines and Vietnam.

This indicates that the export of Indonesian rubber in the form of raw rubber (crumb rubber), which has not been done to increase the added value in the form of processed rubber products that have high added value, but the processing of raw rubber to the next stage of rubber industry products that provide higher added value has been carried out by Singapore, Malaysia, and Thailand. This is in line with the findings of Ansofino, et al. (2018) and (Ansofino and Zusmelia, 2018) which states that the added value of Indonesia's rubber trade is captured by Singapore countries, Malaysia and Thailand. That is why, the trend of Indonesia's rubber trade to these three countries remains high



Source: Own calculation based on data from the Wits World Bank, 2019

Figure 3: Comparison of the intensity of Indonesia's rubber trade with ASEAN countries.



Source: Own calculation based on data from the Asian Development Bank, 2019

Figure 4: Percentage of Indonesia's imports from five ASEAN countries.

because these countries do need a supply of raw rubber from Indonesia to be processed into other rubber industry products that provide high added value, such as swimsuits, automotive industry requirements and others so.

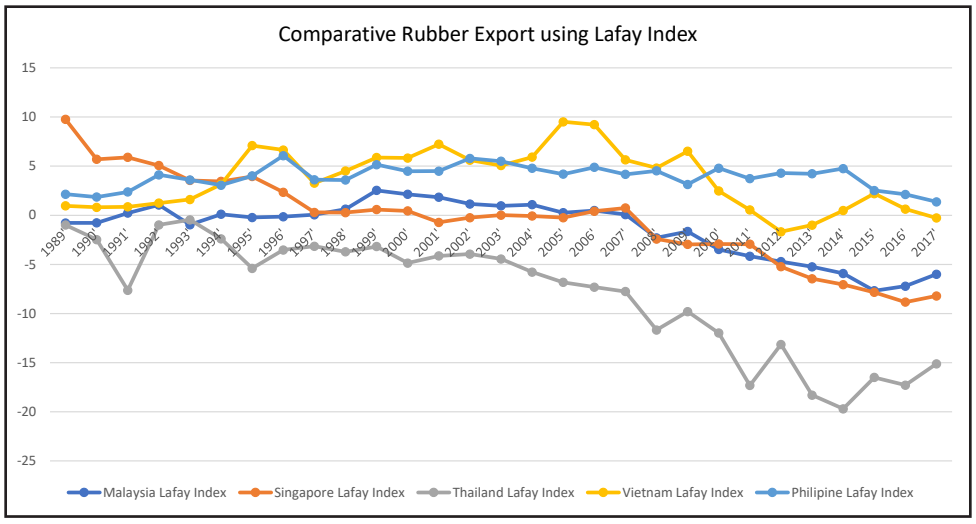
The intensity of Indonesia's rubber trade with the ASEAN countries being the most continuous is with Singapore, Malaysia, and Thailand, the net value of rubber exports to these three countries has continued to decline, but since the economic crisis and global financial crisis, the orientation of Indonesia's rubber exports in the form of raw rubber began widened to Vietnam and the Philippines so that it can be said that the net value of Indonesia's rubber exports increased in Vietnam and the Philippines. This means that Indonesia's high net rubber exports to the Philippines and Vietnam are due to smaller Indonesian imports from the latter country.

Indonesia's imports from the largest ASEAN countries are from Singapore, Malaysia, and Thailand compared to Indonesia's imports from Vietnam, and the Philippines which are much smaller as shown in Figure 4. Indonesian imported goods from Singapore that made Indonesia's competitiveness lower were mainly consumer goods, fuel, intermediate goods, capital goods and machinery, chemicals, and then plastic and rubber goods. All of these imports are processing materials for the processing industry in Indonesia, so of course the economic value is far higher than the economic value of rubber exports to Singapore in the form of raw rubber. The types of goods are similar to Malaysia, where the biggest types of goods imported from Malaysia are fuel, consumer goods, intermediate goods, capital goods, and machinery and electronics, even including plastic, and rubber. This means that the intensity of trade between Indonesia, and the two biggest countries, whose trade with Indonesia so far, has turned out to be more focused on consumer goods and capital goods and even intermediated goods. Even when viewed from Singapore and Malaysia's imports from Indonesia, it is not rubber and rubber products which are the most dominant, even food products and vegetables which are Indonesia's leading commodities and even the economic corridors of the Sumatra region, including the types of imported goods which are not the top priority in Singapore's import composition, and This Malaysia. So it can be said that if you want to increase Indonesia's competitiveness of these two countries, the intensity of Indonesia's trade, especially exports, must be from consumer goods, intermediated goods, fuel goods, capital goods, not raw materials, especially food products whose portions are very small imported. by Singapore and Malaysia from Indonesia.

Figure 4 above shows that Indonesia's imports in ASEAN countries with the type of fuel products, consumer goods, intermediated goods, and capital goods are dominated by 3 countries namely Singapore, Malaysia, and Thailand. After that followed by Vietnam and the Philippines. These five countries are Indonesia's biggest trade partners among other ASEAN countries. However, compared to Indonesia's exports to these countries, the value is much smaller. That is why Indonesia's trade balance with the three ASEAN countries has always been negative. Therefore, Indonesia's leading commodity, specifically economic corridors in the form of crumb rubber, must be of low competitiveness.

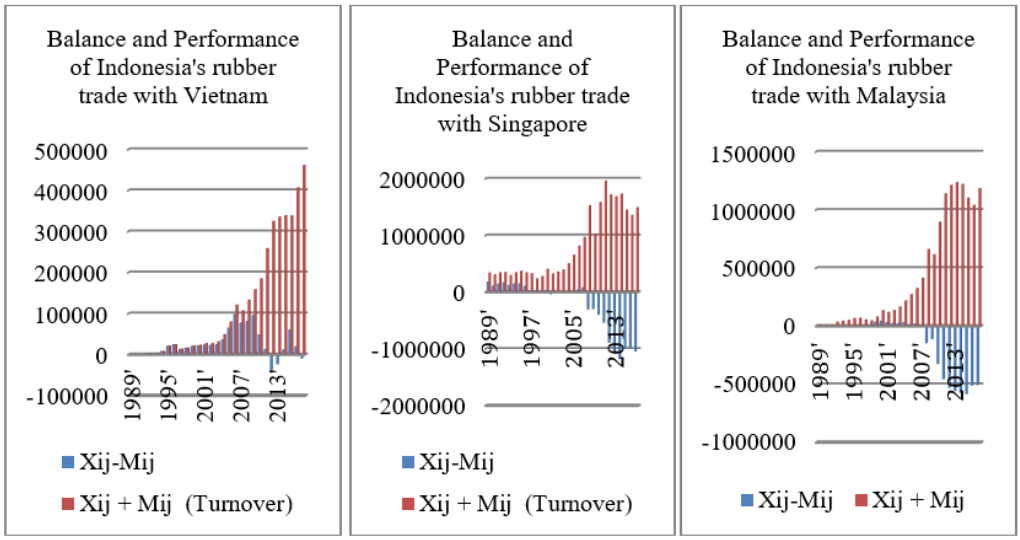
Measurement of the competitiveness of Indonesia's rubber exports to ASEAN countries using the Lafay Index as seen in the results in Figure 5 shows that the competitiveness of Indonesia's rubber exports to Singapore, Malaysia, and Thailand has declined over the past two decades. The drastic decline in the competitiveness of rubber exports was also evident from the low ranking order of Singapore's state imports from Indonesia, the type of rubber commodity occupying the fifth-lowest position for the large portion of Singapore's imported goods types from Indonesia, while Vietnam ranked eighth. The top order for the portion of imported goods from Indonesia in the countries of Singapore and Vietnam remains in the form of consumer goods, intermediated goods, capital goods. Because of the composition of Vietnam's imports place raw materials in the top third, so the turn over of Indonesia's rubber exports to Vietnam is getting bigger.

The competitiveness of Indonesia's rubber exports to Malaysia is better than that of Singapore (see the Figure 5). The types of goods exported to Malaysia, plastic goods, and rubber ranks at the top eight, while the same goods to Singapore rank at the bottom five imported by Singapore from Indonesia. So that the competitiveness of Indonesia's rubber exports to Malaysia is far greater than that of Singapore. So it can be said if the type of Indonesian export goods is still at the level of raw materials, and rubber raw materials, then its competitiveness will be low with countries that have been processing and increasing added value, which can be seen



Source: Own calculation based on data from the Asian Development Bank, 2019

Figure 5: Competitiveness rubber export using Lafay index.



Source: Own calculation based on data from the Asian Development Bank, 2019

Figure 6: Comparison of Indonesia's rubber trade intensity with Vietnam, Singapore and Malaysia.

from the composition of imported goods that place raw goods and agricultural foods as lowest order in importing to his country. Conversely, if the types of Indonesian exported goods are at the level of intermediated goods, consumer goods, and capital goods, then the intensity of Indonesia's trade with ASEAN countries will be dominated by Singapore, Malaysia, and Thailand. The presence of Vietnam, and the Philippines which strengthen Indonesia's competitiveness is more because these two countries still place raw material as the type of goods that ranks in the top five, including rubber.

The Figure 6 above shows that the performance of Indonesia's rubber exports to Vietnam is still experiencing an increase which is shown by its turnover value, but the value of net exports in Singapore and Malaysia has decreased since the period of the global financial crisis hit Indonesia's trade. Therefore, in improving Indonesia's trade performance, especially in the type of rubber commodity, it is necessary to find partner countries that still need raw materials in their imports, such as Vietnam, and the Philippines. A more elegant way to increase trade intensity with ASEAN countries is of course by taking a position on consumer goods, intermediated goods, and capital goods began to avoid types of food goods and goods with other lower value-added products.

Diamond model of Indonesia's rubber export competitiveness

The competitiveness of Indonesia's rubber exports with ASEAN countries which has been calculated using the Lafay Index shows that the competitiveness of Indonesia's rubber exports to Singapore, Malaysia, and Thailand has declined, so far it has been a destination for Indonesian rubber exports. In line with that, the competitiveness of Indonesia's rubber exports has increased with Vietnam and the Philippines. Several factors that affect the competitiveness of rubber exports have been specified by referring to the Diamond model.

Three types of panel data were tested by pooled least square (PLS), fixed effect method (FEM), and random effect method (REM) testing methods. The assumption used for the fixed effect method is the diversity of the competitiveness of Indonesia's rubber exports with the unobserved ASEAN major partners correlated with several unobserved characteristics. While the assumption for the RE method is that the diversity of Indonesia's export competitiveness characteristics that are not observed is uncorrelated with the observed characteristics. Determination of whether the panel data testing model for rubber export competitiveness is in Pooled, FE, or RE, then the Chow-likelihood ratio test, and Hausman Test are used (Bai, 2013).

The results of the diamond model testing which showed the most appropriate model to analyze are the fixed effect model shown by a significant Chow-likelihood ratio value so that the diversity of Indonesia's rubber export competitiveness with the unobserved ASEAN countries correlates with several observed characteristics (Table 1).

	Pooled Method	Fixed Effect Model
Constanta	-43.16	-19.8157**
Consumer Goods	5.77 (1.40)	-2.97 (-0.845)
FDI	2.06 (5.33)**	8.86 (1.77)*
Price Competition	0.1039(3.10)**	0.0666 (2.036)*
Exchange rate	-0.000692(-1.08)	0.000740 (0.47)
Rubber export	2.23 (3.46)**	3.74 (0.89)
Interest rate	2.631 (5.08)**	-0.7048 (-1.858)*
Import	8.69 (1.02)	1.62 (1.95)*
R2	0.805379	0.984398
F Statistic	18.91747	73.612
Sample Periode	2010-2017	2010-2017
Number Observation	40	40

Note: * significant 10%, ** significant level 5%

Source: Own calculation based on data from the Wits World Bank, 2019

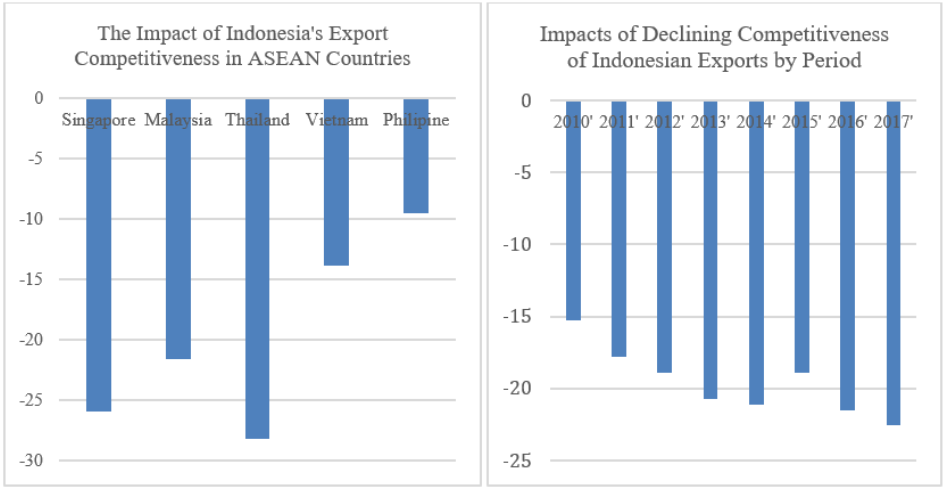
Table 1: Estimation panel of export competitiveness and its components.

After testing the model with the Chow Likelihood Ratio Test, the assumption of Indonesia's export competitiveness is a fixed-effect model for the cross-section, and its period can finally be accepted, because the chi-square cross-section value is 57, 31 and the value of the cross-section chi-square period is 100, 94, this is significant for all levels of statistical testing.

Indonesia's export competitiveness is significantly affected by foreign direct investment (FDI), price competitiveness, rubber export value, and interest rates, whereas consumers good, exchange rate and import values do not significantly and significantly influence the export competitiveness of countries ASEAN, as indicated by the regression results table using the pooled method above. Changes in FDI Indonesia's price competitiveness will have an impact on increasing Indonesia's export competitiveness of US $ 2.06 billion and the US $ 0.1039 billion, respectively. The larger change to increase Indonesia's export competitiveness was contributed by an increase in rubber exports and interest rates of US $ 2.23 billion and the US $ 2.6 billion, respectively.

The decline in export competitiveness can be seen from the negative constant value of -43.16 in the pooled data method, and by -19.8157 in the fixed-effect model. Three countries that have been Indonesia's rubber trade partners, Singapore, Malaysia, and Thailand, have experienced the greatest impact on the decline in Indonesia's rubber export competitiveness in ASEAN countries. This is in line with the third Lafay Index, which is lower than Vietnam, and the Philippines as the more intense rubber trading partner in the last five years. From internal factors alone, the cause of the low competitiveness of Indonesian rubber is in addition to the composition of imports of these three countries which emphasizes on processed products or consumer goods is the quality of Indonesian rubber export products which are still in the form of raw rubber, it is necessary to increase the quality of products to increase added value, (Svatos, Smutka and Miffek, 2018), so with the countries of Vietnam and the Philippines, the portion of rubber products produced by Indonesia becomes the composition of its imports, which ranks fifth of all imported products.

Indonesia's export competitiveness turned out to be a downward trend from the period of 2010 to 2017 export destination countries which contributed the most to the decline in competitiveness were Thailand, Singapore, and Malaysia, compared to Vietnam and the Philippines, as seen in the Figure 7. The highest period of decline



Source: Own calculation based on Fixed Effect Model, 2019

Figure 7: Impact of the declining competitiveness of Indonesia's exports to ASEAN trade partner countries, and their periods.

in export competitiveness occurred in 2017, although competitiveness had strengthened in 2010 and 2015.

The deciding factor for the decline in Indonesia's export competitiveness is the FDI factor, this is in line with the findings of Huo (2019) and (Huo et al., 2019), that the impact of FDI, and the price level on export competitiveness especially agricultural products is positive in emerging market countries, including Indonesia. The interest rate, and the size of rubber exports were able to increase Indonesia's export competitiveness, but this rubber export was no longer significant in the fixed-effect model. FDI, which is believed to be able to have an impact on creating improved technology for processing rubber products, and increasingly efficient management of rubber export companies, (Zhang et al., 2010) turns out that such an impact has not yet occurred in the rubber industry in Indonesia. Specifically in West Sumatra there are 8 rubber exporting companies and all of their products are SIR 10, 20 (**http://www.gapkindo.org/id/cabang/101-west-sumatera**).

Unlike Singapore, Malaysia, and Thailand, their rubber export products are ribbed smoked sheets (RSS 3) which are directly used as raw materials for making aero tires, tubes, footwear, handmade hoses. Singapore needs more technically specific rubber (TSR 20) products for manufacturing medical equipment, engineering, automobile, footwear, condoms, industrial glove, and so on. Noting differences in the quality of rubber products traded in Indonesia in the form of sheets of Indonesian rubber (SIT 10, 20) which are still far from the quality of standard Indian natural rubber (ISNR) (**https://www.thomsonrubbers.com/natural_rubber.html**). So that it can be said that the declining competitiveness of Indonesian rubber exports which is highly determined by FDI, and the level of rubber prices, is evident in the empirical fact that companies engaged in rubber exporters in Indonesia have not processed rubber products that are in the ISNR standard which so far have set 2 types of sheets rubber produced, and marketed in the International trade market, namely: ribbed smoked sheet (RSS), and air-dried sheets (ADS).

In line with the price differences caused by differences in quality among ASEAN rubber producing countries, which has made Indonesia's rubber product export competitiveness decline, it turns out that Indonesia's SIR 20 prices are far lower than the types of RSS, TSR, and SMR produced by Thailand, Singapore, and Malaysia. In January 2020 the maximum price of TSR Singapore reached 174.30 US cent/kg, RSS 3 Thailand the maximum price reached the US 166.01 cents/kg, while the maximum price of SIR 20 GAPKINDO Indonesia at the same time only reached 154.60 US $ cents/kg (see ASEAN rubber price statistics: **http://aseanrubber.net/arbc/index.php/january-2020-side**). Therefore, to increase the price of Indonesian rubber export products, it must meet 2 types of ISNR which become the world rubber trade standard. FDI activities in the rubber industry should focus on this locus.

Conclusion

Based on the main issues, and discussions that have been carried out, conclusions can be drawn from the results and discussions that have been carried out using various analytical tools.

The volume of Indonesia's rubber exports to ASEAN countries has been increasing for the past three decades. The biggest increase in export values, which at present are Vietnam, and the Philippines, in addition to Singapore, Malaysia, and Thailand. There has been a shift in the orientation of Indonesia's rubber exports from the original to Singapore, Malaysia, and Thailand, slowly moving to Vietnam, and the Philippines over the past decade.

There has been a decline in the competitiveness of Indonesia's rubber exports to ASEAN countries, the greatest decline in competitiveness that occurred in Singapore, Malaysia, and Thailand. The factor causing the decline in competitiveness is due to the quality of Indonesian rubber products which are still at the level of raw rubber, which no longer ranks highest in the composition of ASEAN countries' imports. The three countries mentioned have been processing rubber into consumer goods with higher added value.

The decline in competitiveness of Indonesia's rubber exports is evident from the decline in the Lafay index value, and the results of the fixed effect model (FEM) test. Factors that affect Indonesia's export competitiveness that is more dominant are foreign direct investment (FDI), price levels, and interest rates. FDI must be directed at improving the quality of export products following the quality of ISNR and upgrading the quality of rubber export products from SIT 20 slowly to switch to RSS and TSR which prices are higher and directly more beneficial for the manufacture of goods for final consumers.

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Appendix

Dependent Variable: Y?
Method: Pooled Least Squares
Date: 03/01/20 Time: 07:50
Sample: 2010 2017
Included observations: 8
Cross-sections included: 5
Total pool (balanced) observations: 40

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-19.81574	7.433521	-2.665728	0.0145
X1?	-2.97E-06	3.51E-06	-0.845785	0.4072
X2?	8.86E-11	5.00E-11	1.770134	0.0912
X3?	0.066698	0.032744	2.036962	0.0545
X4?	0.00074	0.001574	0.470212	0.6430
X5?	3.74E-06	4.18E-06	0.893487	0.3817
X6?	-0.704846	0.379341	-1.85808	0.0772
X7?	1.62E-05	8.27E-06	1.955168	0.0640
Fixed Effects (Cross)				
_SINGAPORE--C	-6.148406			
_MALAYSIA--C	-1.776322			
_THAILAND--C	-8.352781			
_VIETNAM--C	5.984002			
_PHILIPINE--C	10.29351			
Fixed Effects (Period)				
2010--C	4.574004			
2011--C	2.075178			
2012--C	0.922327			
2013--C	-0.906194			
2014--C	-1.292504			
2015--C	-0.933952			
2016--C	-1.707206			
2017--C	-2.731654			

Effects Specification
Cross-section fixed (dummy variables)
The period fixed (dummy variables)

R-squared	0.984398	Mean dependent var	-4.800534
Adjusted R-squared	0.971026	S.D. dependent var	7.062737
S.E. of regression	1.202208	Akaike info criterion	3.511839
Sum squared residual	30.35138	Schwarz criterion	4.314057
Log-likelihood	-51.23679	Hannan-Quinn criteria.	3.801896
F-statistic	73.61224	Durbin-Watson stat	1.866768
Prob(F-statistic)	0.00000		

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Similarity and Competition of Polish Agri-food Export with the Largest Agricultural Producers in the EU. Analysis of EU, US and China Market

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Abstract

Poland is one of the largest agricultural producers within European Union (EU). Since joining EU in 2004, Poland has significantly increased its agri-food trade turnover and strengthened its net exporter standing in this regard. With the understanding that countries exporting similar goods to a specific market can be considered competitors, the examination covered similarities in Poland's export of agri-food products compared to the two largest agricultural producers in EU, namely Germany and France, in three markets: EU-28, China and United States. The agri-food export was analyzed in terms of structure, value and quality, using ComExt data. The growth of the Polish agri-food trade following the accession to the European Union, allowed the country to become a competitor to the common market's biggest agricultural producers. Poland's competitiveness in the US market in relation to Germany is also rising. On the other hand, looking at the Chinese market, the value of the exported agri-food products is too low to consider Poland a major competitor to Germany or France. Poland's competitiveness in the trade of agri-food products is relatively well covered in the literature, but the studies usually focus on the issue of volume and structure or comparative advantages. The export similarity is omitted, in particular with regard to Central and Eastern European countries (CEEC) and to quality similarities issues. The study also suggests a way to identify countries similar in terms of export structure that is based on entire population results. This study fills in a certain research gap that emerged in the context of CEEC, consisting in the analysis of Poland's export in the background of EU's largest agricultural producers.

Keywords

Agri-food sector, export, structure similarity, international competitiveness.

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Introduction

As per Eurostat (ComExt) data, on the year of Poland's accession to European Union, the agri-food products accounted for nearly 9% of the total export, value at around EUR 5.3 billion. Since the accession to EU in 2004, the dynamics of the export of agri-food products from Poland has risen significantly. In 2019, the export of the discussed products was valued at around EUR 31.5 billion, accounting for 13% of Poland's total export. The agri-food products trade balance also improved, because export has been rising relatively more quickly than import. The trade balance for products of agricultural origin was EUR 0.8 billion in 2004. Growing successively, it reached around EUR 10.4 billion in 2019. Just like pre-accession, EU states have remained Poland's main trade partners. Nearly 75% of all exported agri-food products reached this market in 2004, and around 81% in 2019.

Even before joining EU, CEEC enjoyed close relations with EU states, based on free trade agreements signed in 1995 (Caporale et al., 2012). Despite the growing turnover, trading in some products was still limited due to non-tariff barriers. This problem was ultimately eliminated by joining the European Union, which resulted in opening the market completely (Marques, 2011). A common market exists within EU, within which goods, labor and capital can freely cross the states' borders.

The member states have lifted duties for each other and, as a part of a customs union, set out a common trade policy (Larue, 2018). Such facilitations intensify trade within the common, but may also impact export orientation towards third countries, if only by growing certain industries, caused by access to a bigger market. Finally, trade changes may lead to increased competition among the member states (Pawlak, 2018; Maciejewski and Wach, 2019). This, in turn, leads to deepening the differences in performance and economic growth tendencies in European countries (Bilan et al., 2020; Blázquez-Fernández et al., 2018).

As indicated by Svatoš et al. (2013), following the accession to EU, Poland's agri-food production and trade turnover of agri-food products increased significantly. This translated into increased comparative advantages in food export, both in relation to EU states and in the global market in general. It can be therefore concluded that the competitiveness of the Polish agri-food trade has risen. Svatoš and Smutka (2012) found that, among others, Poland significantly changed the structure of its agri-food trade in the post-accession period, simultaneously managing to get higher unit prices for its goods. These changes may indicate the growing quality of the exported goods, but also to the significance of changes in export structure from the perspective of the growth of competitiveness (Janda et al., 2013). This conclusion is drawn from the simultaneous improvement of comparative advantages in relation to EU states and the altered export structure, which was also confirmed by Bojnec and Fertő (2009). Indeed, the similarity within the structure of export to a given market may point to the fiercer competition among the studied entities (Abrham et al., 2015; De Benedictis and Tajoli, 2007; Bang and Tuo, 2013; Luo et al., 2018; Maciejewski, 2019; Yang et al., 2019).

In the presented context, the objective of the study was to measure the similarity of Poland's export with regard to agri-food products to the export by Germany and France, the two largest agricultural producers in European Union. The purpose of the study is to show the growth or drop of competitiveness in the export of agri-food products to three markets: EU-28, China and United States. These markets have been selected since they are the largest recipients of EU agri-food products. The similarity of the export structure, the export's value and quality were analyzed in each of these markets. Reference literature provides plenty of research on competitiveness of the Polish, and more broadly, EU agri-food export, but is usually focused on the issues of volume and structure or comparative advantages (Torok and Jambor, 2013; Bojnec and Fertő, 2015), but it fails both to study the very similarity of export to a given market, in particular to CEEC, and the quality aspects. Such studies were conducted, by Antimiani et al. (2012), for a bigger group of states in the view of their accession to EU, but only with regard to the value of export for two periods: pre- and post-accession. Based on this research, Poland's increasing competitiveness on the EU-15 market has been identified. There are also several studies that take into account the quality and structure, but only for EU-15 states. For instance, Antimiani and Henke (2007) found that the export similarity on the EU-15 market is low and when quality is taken into account similarity is even lower. Rondinella et al. (2019) found that agri-food export similarity between Italy and Mediterranean countries is higher in North American market than in EU-28 market in terms of structure and quantity, but not quality. Consequently, this study fills in a certain research gap that emerged in the context of CEEC, consisting in the analysis of Poland's export in the background of EU's largest agricultural producers.

Materials and methods

The similarity of agri-food export structures among Poland, France and Germany in individual markets were examined on the basis of data from the Eurostat (ComExt) data base. The agri-food products belong to the first 24 chapters classified subject to the Harmonized Commodity Description and Coding System (HS). The similarity indicators were calculated on the basis of data from the level of 8-digit merchandise disaggregation. The export structures of Poland, Germany and France were compared against each other, on three markets: the US, China and UE-28. The study covered the following 2-year periods: 2004/2005, 2009/2010, 2014/2015, 2018/2019. Choosing 2-year periods allows to limit annual fluctuations that may sometimes occur in international trade. Selected time range allows to trace export similarity changes that have occurred since Poland's accession to the EU.

The first examined index is the Export Similarity Index (ESI), originally used by Finger and Kreinin (1979). This is the simplest measure of the similarity of export of two entities into the third market's entity, aiming to compare only the patterns of export for various product categories. Consequently, it is entirely independent from absolute values and only depends

on the share of individual product categories in total export (Zheng and Qi, 2007). The measure can be represented with a formula:

$$ESI_{ij,d} = \sum_{c=1}^{n} \min(x_{i,d}^{c}, x_{j,d}^{c}) \quad (1)$$

where: $x_{i,d}^{c}$, $x_{j,d}^{c}$ are, respectively, the shares of goods exported (c) from the market (country) i into the target market (d) and from the market (country) j into the target market (d).

The ESI values fluctuate between 0, which represents a complete lack of similarity of the export structure between country i and j, into the target market d, to 1, which represents identical structures of export of the analysed countries into the target market. In this study, the shares of individual goods from HS 1-24 are put against the value of the entire agri-food export. 4689 various goods were analysed with regard to 8-digit disaggregation. The level of disaggregation has a major impact on ESI result (Pomfret, 1981). As indicated by Nguyen et al. (2017), ESI values get progressively lower as the level of data disaggregation rises. Antimiani et al. (2012) indicate that reference literature lacks a method of determining which indicator values show a similarity of export structures. Consequently, an arbitrarily determined threshold value is used. Having in mind that the indicator is sensitive to the level of data aggregation, we agreed that the threshold value over which ESI indicates a similarity of structures should be determined on the basis of index results from the entire population (all EU-28 states in this case).

We applied a method of determining the threshold value that is used in the vector elimination algorithm, used for the purpose of determining groups of objects similar in terms of structure (Chomątowski and Sokołowski, 1978). The first step was to create a symmetrical matrix of diversity regarding the export structure of agri-food products [vjp] among UE-28 states, each one against each other. The diversity indicator, which is the result of subtracting the ESI indicator from 1, was calculated for all pairs. A separate matrix was created for each of the three examined markets, in order to determine their applicable threshold values. The γ threshold was defined as the difference between the arithmetic mean and standard deviation for non-diagonal entries of the matrix [v_{jp}] in 2018/2019, as per the following formula (Kukuła, 2010):

$$\gamma = \bar{v} - S_v \quad (2)$$

with:

$$\bar{v} = \frac{2\sum_{j=1}^{r}\sum_{p>j} v_{jp}}{r(r-1)} \quad (3)$$

where: $\bar{v}$ = average value of non-diagonal entries of the structure diversity matrix [v_{jp}]; r = number of objects compared (countries)

with:

$$S_v = \frac{2\sum_{j=1}^{r}\sum_{j,p} |v_{jp} - \bar{v}|}{r(r-1)} \quad (4)$$

where: S_v = mean deviation of non-diagonal entries of the structure diversity matrix [v_{jp}].

The obtained result was subtracted from 1, so that it can be interpreted as a similarity threshold, rather than a structure diversity threshold. All pairs of countries for which the ESI indicator achieves values that exceed the similarity threshold should be considered similar in terms of the export structure. This method served to determine whether Poland, France and Germany are similar in terms of the examined structure in the analysed markets (ESI results for each pair of EU-28 countries are shown in Appendix. Table A1 shows results on the EU-28 market, Table A2 on the US market, and Table A3 on the Chinese market). The previously mentioned limitations of the ESI indicator, in particular the omission of absolute export values, were taken into account by calculating the product similarity index (PSI) that shows the degree of overlapping of the absolute values of export streams. The higher the values of this indicator, the higher the similarity of export, and in turn, the higher the competitive pressure between entities in a given market (Rondinella at al., 2019). PSI can be represented with the following formula:

$$PSI = 1 - \left[\frac{\sum_{c=1}^{n}\left|X_{i,d}^{c} - X_{j,d}^{c}\right|}{\sum_{c=1}^{n}(X_{i,d}^{c} + X_{j,d}^{c})}\right] \quad (5)$$

where: $X_{i,d}^{c}$, $X_{j,d}^{c}$ are, respectively, the shares of goods exported (c) from the market (country) i into the target market (d) and from the market (country) j into the target market (d).

Just like with ESI, the value of 0 shows the lack of similarity and 1 indicates that there are identical values of export streams in the given market. The real similarity of export streams may be overstated by the PSI indicator due to failure to take into account the goods quality factor. It is possible that the value of export of a specific product from one country is the same as the one from another country in comparison, but with a markedly different quantity

of the shipped goods. This may lead to falsification of the real similarity of export into a given market, where entities who are not competitors may be considered to be ones. Aiming to avoid this situation, the quality similarity index (QSI) was also calculated. QSI takes into account only goods from the same category that are similar in terms of quality. QSI may be calculated with a formula (Antimiani and Henke, 2007):

$$QSI = \left\{1 - \left[\frac{\sum_{c=1}^{n}\left|X_{i,d}^{c,q} - X_{j,d}^{c,q}\right|}{\sum_{c=1}^{n}(X_{i,d}^{c,q} + X_{j,d}^{c,q})}\right]\right\} * \left[\frac{\sum_{c=1}^{n}(X_{i,d}^{c,q} + X_{j,d}^{c,q})}{\sum_{c=1}^{n}(X_{i,d}^{c} + X_{j,d}^{c})}\right] \quad (6)$$

where: $X_{i,d}^{c,q}$, $X_{j,d}^{c,q}$ are, respectively, the shares of goods exported (c) from the market (country) i into the target market (d) and from the market (country) j into the target market (d). Only goods in the same category and similar in terms of quantity (q) are used in the formula.

The goods quality similarity was determined on the basis of export unit values (XUV). This approach is sometimes met with criticism in reference literature (King, 1993), since unit values are largely dependent on the changes in the quantity of individual goods belonging to the same category. These changes may even take place repeatedly during a year. Relying on XUV as a quality indicator may also be flawed due to the often poor quality of data on the quantity of goods in customs documents (Silver, 2009). Doubts aside, there are no data that may represent the real price in a better way, which would make them a better indicator of quality (Bojnec and Fertő, 2010). Many researchers who use unit values as information about the price invoke Stiglitz's (1987) conclusion that even if the information is imperfect, prices reflect the quality and determine the direction of the trade. For example, Anwar and Sun (2018) empirically confirm in their recent study the validity of using the export unit value as a proxy for export quality. This validity has also been confirmed in other studies using these indicators for measuring the quality in international trade (e.g. Hummels and Klenow, 2005; Mau 2019), or specifically in agri-food trade (e.g. Janský, 2010; Smutka et al., 2019). Hallak (2006) also claims that differences in quality are better seen between less homogeneous goods, whereas goods exhibiting uniform features differ in quality to a lower extent.

This study considers goods that satisfy the condition expressed with the following formula to be of the same quality:

$$1 - \left(\frac{\left|XUV_{i,d}^{c} - XUV_{j,d}^{c}\right|}{XUV_{i,d}^{c} + XUV_{j,d}^{c}}\right) \geq 0.9 \quad (7)$$

where: $XUV_{i,d}^{c}$, $XUV_{j,d}^{c}$ are, respectively, the export unit value of goods (c) from the market (country) i into the target market (d) and from the market (country) j into the target market (d).

The examination of differences in the unit value at a high level of disaggregation should indicate goods that are similar in terms of quality. Additionally, a certain level of permissible error was assumed so as not to exclude goods similar in terms of quality from the QSI analysis. The applied inequality is, in a way, an improvement in relation to the inequality used in other studies (Antimiani and Henke, 2007):

$$(1 - \alpha) < \left(\frac{XUV_{i,d}^{c}}{XUV_{j,d}^{c}}\right) < (1 + \alpha) \quad (8)$$

This inequality assumes that the quotient of XUV_i and XUV_j falls into a certain confidence interval determined by coefficient α, set at a range from 0.15 to 0.25.

However, this measure fails to satisfy the principle according to which the comparison of object A with object B should produce the same result as the comparison of object B with object A. In other words, XUV_i / XUV_j is not equal to XUV_j / XUV_i. It is worth noting that although the differences are usually low at a high level of disaggregation, the measure proposed in our study is free from such error whatsoever. Setting the indicator's value at or above 0.9 is equivalent with the value α in the range between 0.15 and 0.25.

In the presented form, QSI may assume values between 0 and 1, where 0 means a complete lack of similarity between the entities with regard to the quality of goods exported to a given market and where 1 means full similarity. In practice, the maximal value of QSI is limited with the value of PSI in that if QSI reaches the value of PSI, then all overlapping streams of exported goods are similar quality-wise, meaning that exporters most certainly compete with each other, because their products have similar utility. As a result, QSI values should be also considered in relation to what part of PSI they constitute.

Agri-food export to the studied markets

EU-28 market

EU states are the major trade partners for Poland, Germany and France alike. The value of intra-EU

trade grew noticeably in 2004-2019 (Figure 1). During the examined period and among the examined countries, the highest values of export to the member states were achieved by Germany, followed by France and Poland.

For all examined periods, meat and edible offal (HS-2) and dairy products (HS-4) accounted for the largest share in the Polish export to the EU market (EU-28). The shares were calculated based on ComExt data. The share of meat and edible offal in the total export of agri-food products was increasing. In 2004/2005 the share accounted for around 15%, while in 2018/2019 for over 17%, which gave a value of almost 9 billion euros. Dairy products accounted for around 12% of the exported agri-food products in 2004/2005, but this share was diminishing and was around 8% in 2018/2019. With regard to the export of agri-food products there was a substantial rise in the share of tobacco and manufactured tobacco substitutes (HS-24), from nearly 2% in 2004/2005 to 13% in 2018/2019. Additionally, preparations of cereals, flour, starch or milk (HS-19) achieved a relatively high share in the export (6-7%) during all examined periods.

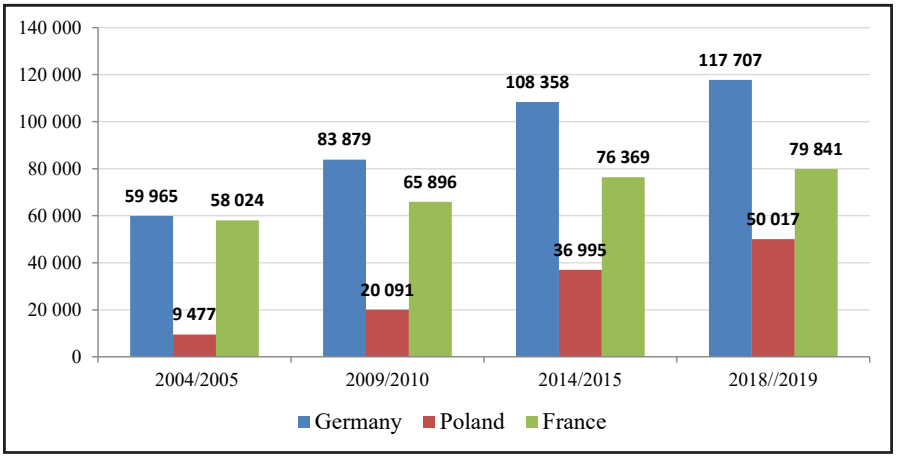
Similarly as with Poland, the largest share in the agri-food export from Germany was achieved by meat and edible offal and dairy products. The share of dairy products in the total export was diminishing. In 2004/2005 these products accounted for 16% of the agri-food export, and in 2018/2019 – 13%, which gave a value of 15 billion euros. For meat and edible offal, in 2004/2005 their share in the agri-food export was 11%, and 13% in 2009/2010, subsequently dropping to 11% in 2014/2015 and to 10% in 2018/2019. A relatively high share of preparations of cereals, flour, starch or milk can be spotted during the examined periods when analyzing the structure of export. These products made up 8-9% of agri-food export to the EU-28 market.

Unlike in Poland and Germany, beverages, spirits and vinegar (HS-22) accounted for the largest share of agri-food export from France into the EU-28 market. These products reached over 17% of the total export during each of the examined periods. The value of beverages, spirits and vinegar was over 53 billion euros in 2018/2019. Dairy products also had a relatively high share in the export of agri-food products. The value of sales of dairy products in the UE-28 market remained at a similar level, of around 11-12% of the total export, during all examined periods. A relatively high share of cereals (HS-10) was noted in 2004-2019 in the export of agri-food products to the UE-28 market. Cereals accounted for around 10% of the exported goods for all examined periods.

US market

When analyzing the export of agri-food products to the US and Chinese markets, one has to account for the existing trade agreements that constitute of the key elements of EU's trade policy. Such agreements may focus on limiting or eliminating tariff barriers or creating a customs union, thanks to the removal of customs duties and setting out common customs rates for foreign importers (Preeg, 1998). European Union was often approached as a strong player on the international market, because the size of the uniform European market and the organisational and legal structure allowed the EU to strengthen its position in international trade negotiations (Meunier, 2005; Meunier and Nicolaïdis, 2006).

The cooperation between EU and USA has been



Source: Own elaboration on ComExt data

Figure 1: Agri-food exports to EU-28 (in million euros).

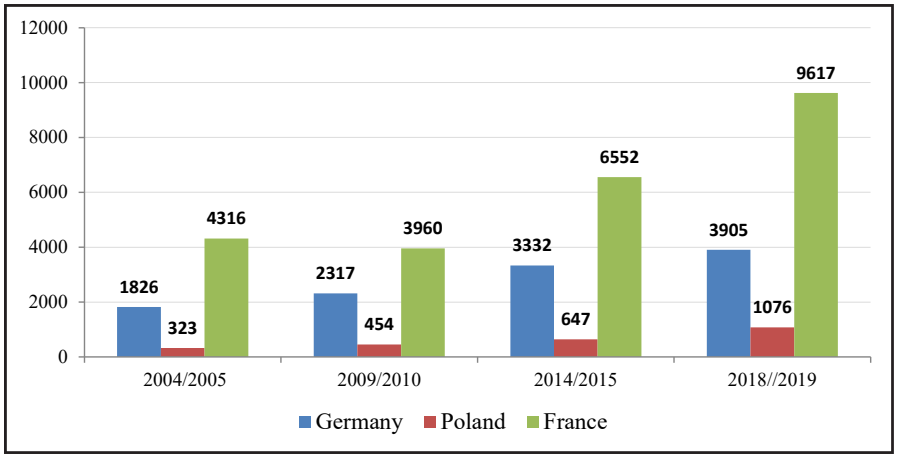
growing closer and closer for many years. It is here worth mentioning the EU–US Declaration Initiative to Enhance Transatlantic Economic Integration and Growth of 2005, in which the European Union and the United States vowed to seek ways for strengthening transatlantic economic integration and to realize the competitive potential of their economies. Another important element in reinforcing the transatlantic relations was the creation, in 2007, of the Transatlantic Economic Council, a platform for holding negotiations between the EU and the US, aiming at a deeper integration of their economies (Tocci, 2008). In 2013, the US and the EU commenced negotiations on a new trade agreement – the Transatlantic Trade and Investment Partnership, an attempt to reinforce the existing alliances (Novotná et al., 2015).

The value of agri-food export from Poland, Germany and France to the American market was constantly rising in 2004-2019 (Figure 2). According to ComExt data, the value of export from Germany and France increased over two times. The value of the Polish agri-food export to United States increased by over three times.

In 2004/2005 and in 2009/2010, beverages, spirits and vinegar had the biggest share in the export of agri-food products from Poland, reaching almost 25%, along with meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations there of (HS-16), which accounted for 24% of agri-food export. In the subsequent period their share dropped to around 20%, but the export of fish and crustaceans, molluscs or other aquatic invertebrates (HS-3) increased rapidly, to over 16% of the total export. In the following years, namely 2014/2015 and 2018/2019, the share of meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof in the export of agri-food products was decreasing, down to 12.5% in 2018/2019. There was a visible increase in the export of meat and edible offal, constituting around 18% in 2014/2015 and nearly 24% in 2018/2019, which gave value of over 251 million euros.

During all examined periods, the biggest share in the agri-food export from Germany to the US market belonged to beverages, spirits and vinegar and to coffee, tea, mate and spices (HS-9). However, their share in the total export was decreasing, to reach 15% for beverages, spirits and vinegar in 2018/2019 and 17% for coffee, tea, mate and spices, whereas it was, respectively, 37% and 18% in 2004/2005. A significant rise in the export of products of the milling industry (HS-11) Their share in the total export was constantly growing during all examined periods. In 2004/2015 the share accounted for nearly 3%, while in 2018/2019 for 9%.

Just like with Germany, the main products sold by France to US were beverages, spirits and vinegar. These accounted for almost 80% of all agri-food exports in all examined periods, and the value of their exports was over 7 billion euros in 2018/2019. Dairy products had a relatively high share in the French export of agri-food products in 2004-2019. Their share in the total export fluctuated between 4% and 6%. The remaining groups of products exported from France had a relatively low share in the total export of agri-food products, around 1-2%.



Source: Own elaboration on ComExt data

Figure 2: Agri-food exports to the United States (in million euros).

Chinese market

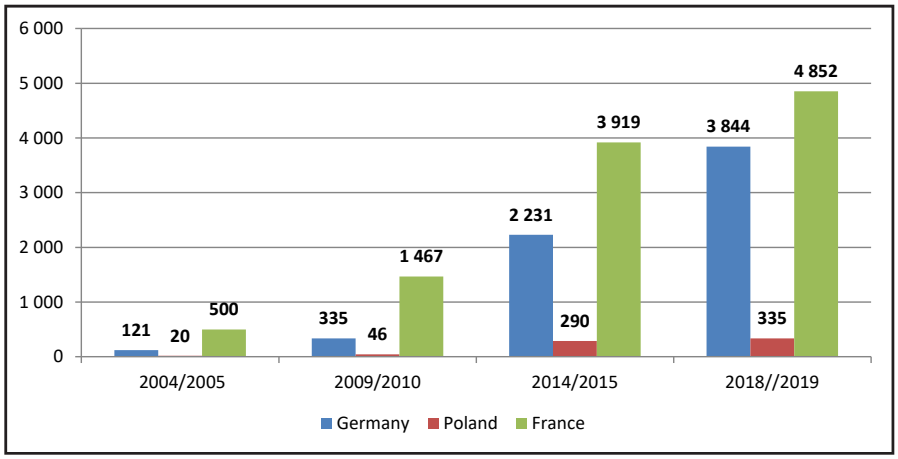
The accession of China to the World Trade Organization (WTO) in 2001 had a large impact on the condition of agri-food trade relations between the EU and China. Following the accession to WTO, China increased import allowances for agri-food products in 2001-2004 (Antimiani and Henke, 2007; Niemi and Huan-Niemi, 2007). The official strategic partnership between China and the EU was initiated in 2003 and prompted the intensification of trade. In 2015, the UE elected to enhance cooperation with China (Brugier, 2017). The solidified economic relations lead to a substantial increase in trade, which eventually made China the EU's second biggest trade partner, following the US (Fang and Skahur, 2018). The resolution of the European Parliament, dated September 12, 2018, on the relations between the European Union and China underscores that China is the fastest growing market for food products from the EU.

In 2004-2019, Poland, Germany and France increased their export of agri-food products to the Chinese market (Figure 3). Poland's export volume was the lowest, with Germany and France achieving markedly higher numbers, which, after 2010, became more similar to each other.

The Chinese market mainly received dairy products from Poland. Starting from 2004, their share grew from period to period, to reach nearly 40% of the agri-food exports in 2018/2019, which was around 130 million euros. A large share of products of animal origin (HS-5) in the export was also reported in 2004/2005 and 2009/2010. These products accounted for around 40% of all agri-food products sold, however, their share dropped rapidly to below 3% in 2014/2015. During this period, the export of meat and edible offal saw another rise. These products accounted for 20% of the total export in 2004/2005, but this volume dropped to less than 2% in the subsequent period. In 2014/2015 and 2018/2019 the sales of meat and edible offal grew again, resulting in achieving a share of around 17% of the exported agri-food products. Such far-reaching changes in the export of agricultural origin products may be affected by quality standards of certain groups of products, the global financial crisis of 2008 and import limitations introduced by China (see e.g. Guo et al., 2011; Priede and Feng, 2017; Taylor and Jaussaud, 2018).

Similarly to Poland, the largest share in the export from Germany in 2004/2005 belonged to products of animal origin (around 24%), whereas in other periods these were dairy products, which constituted around 20% of the exported agri-food products in 2009/2010 and 2014/2015 and around 15% in 2018/2019. 2009/2010 and 2014/2015 saw the rise in the export of beverages, spirits and vinegar, with a share of 19% in 2009/2010 and 15% of the total exports in 2014/2015. Additionally, the sales of meat and edible offal rose significantly in 2014/2015. These products' share in agri-food export was nearly 36% in 2014/2015 and rose to 44% in 2018/2019.

Beverages, spirits and vinegar accounted for the largest share of France's export to China. For all examined periods they accounted for, respectively, 25%, 61%, 42% and 45%. In the last analyzed period it was more than 2



Source: Own elaboration on ComExt data

Figure 3: Agri-food exports to China (in million euros).

billion euros. Increased exports of cereals (HS-10) were also recorded in 2004/2005 and 2014/2015. Their share in the total agri-food export was nearly 23% in 2004/2005 and 25% in 2014/2015. The last examined period, 2018/2019, saw the rise in the export of meat and edible offal and dairy products. For meat and edible offal that meant a rise to 11% in the total export and to 12% for dairy products.

Results and discussion

Similarity of export in the EU-28 market

In each instance, when analyzing the similarity of export between the examined countries, the threshold value determined on the basis of similarity between all EU-28 is of importance. It indicates whether the countries can be considered similar in terms of export structure in a specific market. Crossing the threshold value by several countries means that they share such a similarity. In the EU-28 market the threshold value of ESI was 0.341. This means among Poland, Germany and France there is a similarity in the structure of export, with the exception of France and Poland in 2004/2005, when ESI fluctuated within the range of the threshold value (Table 1). The highest similarity of the export structure of agri-food products can be seen between Germany and Poland, where meat and edible offal, dairy products and preparations of cereals, flour, starch or milk enjoyed a high share throughout the entire examined period. The exports of fresh or chilled bovine meat (HS-02013000) and meat of domestic swine (HS-02031110) were particularly similar in the meat and edible offal group. In the case of dairy products, the highest similarity in the share of exported products was observed for milk and cream (HS-04012091) and for natural butter (HS-04051019). The analysis of the export of the preparations of cereals, flour, starch or milk group shows the highest similarity between food preparations for infant use (HS-19011000) and for sweet biscuits (HS-19053119). It can be seen that the similarity of the agri-food export structure between Poland and Germany was rising considerably until 2009/2010, to remain at a similar level afterwards.

The situation looked differently when viewing the overlapping of export streams, or PSI in other words. Improving results for Poland and Germany were being observed period by period, which was caused by the growth of value of the Polish agri-food exports, at a much quicker pace than in Germany. This is indicated by the increasing competition between the two countries. This happened, in particular for product groups such as meat and edible offal and tobacco and manufactured tobacco substitutes. A significant increase in the value of exported products, and thus a much higher similarity to Germany, was observed for frozen bovine meat (HS-02023090) and cigarettes (HS-24022090). For these products, the value of export from Poland was growing much faster than the value of German export, resulting in equalization of the trade volume, and even larger export from Poland than from Germany in the last examined period. The generally lower values of PSI in comparison to ESI indicate that the potential of real competition is limited by absolute values (Antimiani et al., 2012). Still, the values of both indicators are approaching each other, pointing to a similarity both with regard to the structure and to the overlapping of the streams of value of export between Germany and Poland.

The examined period also saw a marked increase of QSI values, which indicated a growing competition with regard to the quality of goods offered in the EU-28 market, between Poland and Germany. Indeed, the QSI indicator constituted around 50-55% of the PSI value throughout all examined periods. It may be therefore concluded that over half of the agri-food products exported from Poland and Germany, whose streams overlapped, is similar in terms of quality. The highest similarity was shown in groups such as meat and edible offal and dairy products. Definitive similarity in terms of quality was observed, among else, in meat of domestic swine (HS-02032955),

	ESI				PSI				QSI			
	04/05	09/10	14/15	18/19	04/05	09/10	14/15	18/19	04/05	09/10	14/15	18/19
DE-PL	0.431	0.518	0.510	0.507	0.211	0.306	0.381	0.422	0.119	0.149	0.206	0.216
DE-FR	0.445	0.471	0.482	0.470	0.444	0.457	0.453	0.448	0.266	0.228	0.252	0.254
PL-FR	0.338	0.360	0.369	0.362	0.186	0.277	0.338	0.346	0.067	0.106	0.135	0.173

Source: Authors' calculation based on the 8-digit ComExt trade data

Table 1: Export similarity indicators for Poland, Germany and France on the EU-28 market.

but also in turkeys (HS-02072620). The dairy products group showed the highest similarity for milk and cream (HS-04010000 and HS-04015039). On the other hand, the largest quality differences among exported products were shown in vegetable saps and extracts (HS-13) and in vegetable planting materials (HS-14) groups. The discussed similarity indicators of the export of agri-food products for Poland and Germany show a significant increase of competitiveness in the EU-28 market between these countries in the examined period. The underlying reason was that Poland was increasing both the value and the quality of the goods exported to the common market, becoming more competitive in the process.

Similar dynamics as for Germany and Poland was exhibited by ESI in the case of Poland and France. At first, ESI's values rapidly rose in the examined period and later remained at an approximate level. Still, the structure of the agri-food exports to EU-28 between Poland and France was visibly less similar to the structure between Germany and Poland, but, starting from 2009/2010, it exceeded the threshold value, indicating a similarity in the examined period. This was mainly caused by similar shares in the structure of export of such product groups as dairy products and preparations of cereals, flour, starch or milk. Similarity increased in particular for milk and cream (HS-04012091) and natural butter (HS-04051011), but also for food preparations for infant use (HS-19011000). In other words, the same products as for Poland and Germany.

Similarly to Poland and Germany, the PSI values for Poland's and France's agri-food exports also increased. These values were rising during the entire examined period and visibly approached the ESI values. In particular, the growing competition in the export of similar goods was caused by the overlapping of values of streams with regard to cocoa and cocoa preparations. The examined periods showed approaching export values for chocolate (HS-18069019) and spreads containing cocoa (HS-18069060). The QSI values between Poland and France also rose significantly. Whereas this indicator was 0.067 in 2004/2005, constituting around 1/3 of the PSI value, it reached nearly half of the PSI value in 2018/2019. The increased similarity of the export in terms of quality was the effect of the significant increase of similarity across most groups of agri-food goods, particularly such as meat and edible offal and dairy products. Marked similarity in terms of quality was visible for products such as meat of swine (HS-02031110) and (HS-02031219), for milk and cream (HS-04012099) and for fresh cheese (HS-04061050). The largest quality differences could be observed for products of animal origin (HS-5), vegetable saps and extracts and for vegetable planting materials.

Speaking of the similarity of the export of agri-food products in the EU-28 market between Germany and France, the analyzed indicators did not change visibly in the examined periods. Starting from 2009/2010, ESI was even lower than in the case of Germany and Poland, but the values of PSI and QSI were significantly higher for Germany and France. The PSI values were also close to the ESI values, which indicates similarity both in the structure of export and its value. The main products responsible for such a large similarity were fish and crustaceans, beverages, spirits and vinegar, and in particular products such as shrimps (HS-03061792) and water (HS-22021000). The QSI indicator amounted to over 55% of the PSI indicator in the examined years, with the only exception being 2009/2010, when QSI achieved a lower value. This situation should be associated with the turmoil affecting international trade in the wake of the global financial crisis. Although the agricultural sector has always been considered immune to various economic difficulties, the financial crisis of 2008 affected it nonetheless. Growth slowdown was observed, along with a reduction in trade flows, caused by imbalance of demand and supply (Crescimanno et al., 2014). The detailed analysis of data shows that the similarity in the quality of France's and Germany's export was high for meat and edible offal, dairy products and for beverages, spirits and vinegar. In particular, similarity was observed for products such as meat of bovine animals (HS-02012050 and HS-02012090) and for water (HS-22021000).

The analysis of the similarity of the agri-food exports to EU-28 shows that all analyzed countries can be considered competitors. The competition is particularly high between Germany and France and between Germany and Poland and slightly less intensive between Poland and France. During the examined period, Poland noticeably increased its competition towards the analyzed partners by increasing the value of export to the common market and by means of increased quality of the exported agri-food products. The analysis showed that the values of PSI and QSI indicators with Poland's partners are approaching the ones observed among long-term competitors

in the EU-28 market - Germany and France. The 15 years that passed since its accession to the EU was used well by Poland, with regard to the growth of the agri-food export, allowing the country to reach a level at which it can compete in the common market against the region's largest agricultural producers. The obtained results are consistent with the studies on the increase of Poland's competitiveness in the common market, following the country's accession to the European Union (Antimiani et al., 2012) and with the studies showing the rise of comparative advantages in Poland's agri-food trade in the more recent period (Bojnec and Fertő, 2015). Moreover, the studies indicate that this direction has been maintained and that an increasing quality similarity is being observed among Poland, Germany and France.

Similarity of export in the US market

When analyzing the exports from Poland, Germany and France to the American market, the threshold value allowing to identify an existing similarity of the export structure was 0.118. Assuming that all values equal to and higher than the threshold value indicate a similarity between the countries, it may be concluded that in the case of Poland, Germany and France there was a similarity of the export structure determined with the ESI indicator (Table 2). The only period when there was no similarity between Poland and France was 2018/2019. The values of these indicators are very low despite the fact that the structure of export to the US is very similar in the examined countries when comparing to other EU states. This indicates that there is no intensive competition in the trade of agri-food products among EU countries on the US market. Among the examined countries, the highest similarity of structure of the exported agri-food products applied to Germany and Poland. From 2009/2010 on, the values of the indicator were constantly growing. The rise of the similarity of the export structure was affected the most by the following groups: cocoa and cocoa preparations and beverages, spirits and vinegar, in which Poland's and Germany's shares in the total agri-food exports were approaching. Within the examined groups, the highest similarity of structure was observed, among else, for chocolates (HS-18063210 and HS-18069039) and also for beer (HS-22030009).

Lower values can be observed for the PSI indicator, although the growing trend persists, just like for ESI. The markedly lower PSI values indicate a lower similarity with regard to the value of the exported agri-food products. The indicator's value was affected by the overlapping streams of the exported product groups, such as edible vegetables and certain roots and tubers and preparations of vegetables, fruit, nuts or other parts of plants, of which the highest similarities occurred for dried vegetables (HS-07129090) and for jams, among else HS-20079933.

Among the analyzed indicators for Germany and Poland, the lowest value was reached by QSI. The values were fluctuating during the first examined periods, reaching around 35-43% for PSI, indicating that the exported products did not have a high level of similarity. QSI only reached around 50% of the PSI indicator in the last period, which was a sign of the growing similarity of the quality of agri-food products exported to the US market, further pointing to the intensifying competition between Germany and Poland. The rise of similarity was affected by groups of products like dairy products and preparations of vegetables, fruit, nuts or other parts of plants. A noticeable similarity was particularly visible for cheese (HS-04061050) and sauerkraut (HS-20059960). It must be noted that QSI values are low, but their growth during the examined period shows that Poland and Germany may be considered to be competitors in the discussed area in the US market.

A lower similarity in terms of the exported agri-food products may be noticed for Germany and France. Initially, the ESI values were on the rise, but they started to decline since 2014/2015. A decrease in the similarity in terms of the structure of export of product groups such

	ESI				PSI				QSI			
	04/05	09/10	14/15	18/19	04/05	09/10	14/15	18/19	04/05	09/10	14/15	18/19
DE-PL	0.182	0.166	0.203	0.227	0.106	0.110	0.118	0.145	0.037	0.047	0.046	0.073
DE-FR	0.165	0.178	0.155	0.152	0.176	0.192	0.152	0.134	0.040	0.048	0.042	0.022
PL-FR	0.142	0.165	0.125	0.109	0.065	0.075	0.056	0.051	0.015	0.010	0.008	0.011

Source: Authors' calculation based on the 8-digit ComExt trade data

Table 2: Export similarity indicators for Poland, Germany and France on the US market.

as products of the milling industry and beverages, spirits and vinegar contributed to the reduction of the indicator's value. Despite the drop in ESI, during all examined periods there was a similarity, between Germany and France, in the structure of the exported products, when compared to all EU states. One of the contributing factors were the similar shares in dairy products, of which natural butter (HS-04051011) exhibited the highest similarity. Despite the reduced share of the group beverages, spirits and vinegar in the export, the category of white wines (HS-22042138) exhibited a high similarity in the structure of agri-food exports.

Markedly higher values were observed for PSI, which means that export shares and value streams of the exported goods were overlapping to a large extent, simply meaning that they were similar. Just like in the case of ESI, these values were decreasing starting with the 2014/2015 period. In particular, the PSI value was affected by the similar values of the exported edible vegetables and certain roots and tubers. Large streams of mutually overlapping export values may also be observed for vegetables, e.g. HS-07108095. The PSI values exceeding ESI in 2004/2005 and in 2009/2010 are mainly the result of the fact that nearly 80% of France's agri-food exports are beverages, spirits and vinegar, whereas the remaining products have a low share in the export. Consequently, higher similarity was more often seen in the values of export of individual groups, rather than in their shares.

The reduction in the PSI value also affected the value of QSI. Not only very low QSI values can be observed, but they also have been dropping since 2009/2010. This means that, fundamentally speaking, there are no quality similarities among the exported agri-food products. Despite the fact that the values of the exported products, both from Germany and France, were growing during all examined periods, they were overlapping less and less. The quality similarity was also unaffected by the increased export values. The groups showing similarities were changing during the examined periods, so it is difficult to find one that would be similar in this regard, which confirms the lack of similarity in the quality of agri-food exports between France and Germany.

The lowest similarity of the export structure was observed for Poland and France. The similarity was further diminishing to reach 0.109 in the last examined period. This means that in the last examined period, the structure of the exported agri-food products was not similar even when compared to results from all EU states. The lowering similarity of the shares of dairy products and beverages, spirits and vinegar impacted the changes in the structure of agri-food exports and of the ESI indicator. Major changes were observed in products such as cheese, e.g., Emmental cheese (HS-04069013), and in mineral water (HS-22011019).

For PSI, the values did not cross 0.08 in the entire period. Moreover, starting from the 2009/2010 period, PSI was decreasing. A similarity in the export value was only observed for edible vegetables and certain roots and tubers, and beans (HS-07102200) in particular. As far as QSI goes, it also exhibits low values that indicate lack of competition between Poland and France in terms of the quality of exports to the US market. Further, the share of QSI in PSI values was between 13% and 23%, but the overall values of the indicators were so low that it must be concluded that there is no competition with regard to the export of agri-food products between France and Poland.

The analysis of the exports from Poland, Germany and France to the American market shows that only Germany and Poland may be considered to be competitors, even though at low intensity. The rising similarity indicators point to the growing competition within the field of exported products and their approximation in terms of quality. During the examined period, Poland and Germany noticeably increased the volume of agri-food exports to the US, affecting, in this way, the rising values of the analyzed indicators. When analyzing the selected periods in terms of price changes, one can identify approximating unit values of products, whereas these values were markedly higher in Germany than in Poland in the initial periods. It should be noted that the significantly lower values of similarity indicators for the exports to the US market, in comparison to EU-28, are caused by more restrictive trade conditions, especially in the food sector. These conditions make it difficult for the analyzed countries to intensify export in this field. Similar conclusion comes from Maltseva and Chupina (2019) analysis of EU-US barriers in agri-food trade. According to their study, tariff barriers on agricultural transatlantic trade are relatively low at first sight. However, they hide significant tariff peaks in sensitive products – especially in dairy and meat sector. On one hand, obtained results are consistent with Antimiani et al. (2012) in case of Germany, which showed that

Poland raised its agri-food products competition with Germany in terms of PSI after the EU accession on extra-EU markets. On the other hand, Antimiani et al. (2012) found that competition with France was rising, which is in opposition to the obtained results in sense that this direction changed on US market following first few years after Poland's EU accession.

Similarity of export in the Chinese market

According to the conducted calculations, the similarity of the structure of export to the Chinese market is bigger than in the case of American market, as shown by the higher ESI values. This is also manifested by the calculated threshold similarity value for all EU states, which is 0.186 for China - almost 0.07 more than for USA. This is despite the fact, that in terms of value, the export to China is much lower than to the US, both in the case of the analyzed countries and for the European Union in general. Consequently, a lower number of various goods are exported to China, as evidenced by the detailed ComExt data at the 8-digit level.

Relatively high ESI values were observed between Poland and Germany, with the exception of a lower value in 2009/2010 (Table 3). Until 2010, both Poland and Germany recorded low values of exports to the Chinese market and major fluctuations in the types of supplied products. Only two groups of products affected the structural similarity in this period with no changes: whey (HS-04041002) and potato starch (HS-11081300). A high similarity in the export structure was observed in 2014-2019 for milk and cream and for food preparations for infant use. PSI not only had markedly lower values, but also failed to show any rising tendencies. This was caused by the more dynamic rise of the value of export from Germany than from Poland, especially starting from 2014/2015. QSI also assumed very low values, due to a similar value achieved only for milk and cream and for food preparations for infant use. Taking into consideration all three indicators, it must be concluded that Poland and Germany are not competitors in the Chinese market with regard to agri-food exports. This is, in particular, caused by the generally low value of export from Poland in comparison to Germany.

When compared against France, Poland achieves even lower export similarity indicators than in the case of Germany. Here, ESI does not exceed the calculated threshold value of similarity, except for the last period, and even then this indicator's value is still low. Export similarities are also not shown in PSI values, not to mention the very low QSI values. For all three analyzed markets, the highest similarity in terms of agri-food exports was observed for Poland and Germany. Speaking of Poland and France, there does not seem to be a single product on the Chinese market for which the two countries can be considered competitors. It should be noted that the export from France to China exceeded even Germany's exports, which creates even wider gaps between the export from Poland and from France. It is impossible to predict any improvements, because the indicators are ambiguous and their values are low. To effectively compete in China against the largest agri-food producers from the EU, Poland would probably have to increase the value of exports.

However, the rising competition in the Chinese market is noticeable between Germany and France, as evidenced by the growth of the analyzed similarity indicators. It is hard to show any similarities in the export in the first examined period, 2004/2005. In terms of share in structure, pork export showed a similarity, but only to a moderate extent, but it went on to grow considerably in subsequent periods. In 2014/2015 and 2018/2019, the growth of the ESI value was affected by the export of pork and of milk and cream, and also of food preparations for infant use. The competition was rising most dynamically in the latter case. Throughout the two discussed periods, PSI exceeded ESI mainly due to the dominating share of wines and cognac

	ESI				PSI				QSI			
	04/05	**09/10**	**14/15**	**18/19**	**04/05**	**09/10**	**14/15**	**18/19**	**04/05**	**09/10**	**14/15**	**18/19**
DE-PL	0.314	0.182	0.232	0.285	0.173	0.103	0.109	0.106	0.060	0.029	0.040	0.030
DE-FR	0.143	0.190	0.228	0.310	0.121	0.136	0.244	0.324	0.017	0.080	0.101	0.136
PL-FR	0.171	0.083	0.131	0.186	0.055	0.042	0.057	0.060	0.006	0.003	0.020	0.017

Source: Authors' calculation based on the 8-digit ComExt trade data

Table 3: Export similarity indicators for Poland, Germany and France on the Chinese market.

in France's export, which reduces the shares of other categories and limits structural similarity. Still, pork, milk and cream, and food preparations for infant use, were also similar in terms of value stream overlapping.

QSI was also rising and amounted to nearly 60% of PSI in 2009/2010, mainly due to the quality similarity of pork and milk and cream exported from Germany and France. Products from the milk and cream group and selected pork meat products (HS-02032915) kept a similar quality in 2014/2015, but in the second case, the French pork exhibited significantly higher quality at times (among else HS-02064900 and HS-02032959). This translated into a general rise of QSI, but in relation to PSI it reached 42%. In 2018/2019, Germany and France equalized in terms of quality in the export of pork and maintained competition in the group of milk and cream products. Speaking of food preparations for infant use, which have the biggest impact on high PSI and ESI values, the quality of export from France is much lower than that from Germany. This causes QSI to remain at a relatively low level. It is interesting that in the group of food preparations for infant use, it is Poland that shows quality similarity to Germany, but the value of export is too low to consider Poland a potent competitor in this market.

EU states have comparative advantages in agri-food trade with China, in particular with regard to basic products such as: cereals, preparations of cereals, meat, dairy products, or spirits that are not produced in China (Pawlak et al., 2016). Being high-volume producers of such products, Germany and France seem to be using these advantages and compete in the Chinese market more and more intensively. Still, Poland's competition is low, despite the country's comparative advantages in dairy products or preparations of cereals, flour, starch or milk (Wang and Pawlak, 2019). This is mainly caused by excessively low value of exports to China, in comparison to the analyzed partners, or trading in goods of varying quality. It can be seen that Poland's comparative advantages in terms of some agri-food products, which are similar to Germany and France, do not necessarily translate into real competitiveness in each market partially due to export quality differences between countries. It can be linked to trade costs between China and EU involving agri-food products. Fang and Shakur (2018) stated that these cost are falling, although remain abnormally high which is especially problematic for less developed countries in EU. Obtained results also confirms Guo et al. (2015) research which shows that despite a significant structural break during financial crisis, relationship of agri-food trade between China and Germany was developing stably. Moreover, German agri-food export to China developed to the extent that allows to compete with France whose export was previously better established on Chinese market.

Conclusion

The conducted analysis of the similarity of export of agri-food products from Poland, Germany and France showed a significant competition among the examined countries in the EU-28 market. Since its accession to the EU, Poland significantly increased its agri-food exports to the common market, joining the already competing Germany and France in the process. Apart from increased value of export, a rise in similarity was also observed in the quality of the sold goods. Poland's increased competition against Germany was also observed in the US market, where agri-food products similar in terms of value and quality were being sold with growing intensity. Dairy products and preparation of vegetables played a major role in the latter case. The situation was different for French export, which was gradually becoming less similar to the German export, especially from the quality perspective. A complete lack of similarity was observed for Poland and France in the American market. Only Germany and Poland, of the examined countries, may be considered competitors on this market. The competition between these two countries is not highly intensive, but is rising from period to period.

The analysis of agri-food exports to the Chinese market showed high similarity in terms of structure between Poland and Germany, but Poland's export value is too low to speak of any effective competition in this market. This also results in no similarity with regard to the quality of the exported products within the overlapping value streams. Nevertheless, Germany and France are competitors in the Chinese market and they significantly increased the similarity of the export of agri-food products in the examined period. This applied both to the value aspect and, though to a lesser degree, to the quality aspect. There is no similarity between Poland's and France's export to the Chinese market. In each of the examined markets, Poland's agri-food export was more similar to the export

from Germany than to the export from France. Generally, Poland is only competing with France in the discussed scope in the EU-28 market.

The conducted analysis fills in the gap in the research on the similarity of the export of agri-food products, where the issue of quality of products is often disregarded. Very little attention is also paid to CEEC which, following their accession to the EU, could benefit from the opening of new markets - potential export directions. Three similarity indicators were used throughout the study: ESI, PSI and QSI, which allowed a comprehensive analysis of the agri-food exports. A method was also proposed to determine the similarity of the structure of export on the basis of similarity results for the entire population, due to ESI's high sensitivity to the level of data aggregation. This constitutes a certain improvement in comparison to an arbitrarily accepted value over which countries should be considered similar in terms of the structure of export. Regardless, caution is still warranted when analyzing the results and the indicator's absolute value should be taken into account. A limitation is imposed by the certain degree of sensitivity of all similarity indicators to the level of aggregation of data and caution must be exercised when interpreting the obtained results, paying attention to their changes over time and mutual relations, not just absolute values. The authors used a method of their own design to measure the similarity of quality for the purpose of quality analysis with the use of export unit values. The new method produces the same results when comparing object A to object B, as when comparing object B to object A. This also constitutes a certain improvement in relation to the method previously used in reference literature. Future research may focus on Poland's relations with other EU agri-food exporters or on the relations of other CEEC countries, as these are issues rarely addressed in reference literature

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Appendix

	AT	BE	BG	CY	HR	CZ	DE	DK	EE	ES	FI	FR	UK	EL	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
AT	1	.398	.256	.100	.349	.408	.492	.332	.310	.272	.231	.420	.370	.204	.374	.271	.333	.300	.274	.313	.090	.353	.421	.233	.252	.231	.347	.373
BE		1	.241	.103	.317	.405	.498	.309	.274	.296	.244	.410	.423	.219	.292	.273	.334	.297	.267	.321	.073	.470	.408	.304	.225	.254	.314	.326
BG			1	.059	.354	.285	.273	.147	.220	.195	.155	.304	.238	.192	.408	.124	.221	.254	.145	.301	.036	.220	.236	.175	.432	.177	.286	.313
CY				1	.068	.075	.112	.089	.065	.082	.054	.088	.085	.075	.072	.061	.082	.060	.071	.082	.041	.089	.078	.080	.053	.054	.095	.078
HR					1	.429	.381	.238	.266	.221	.192	.350	.288	.222	.380	.210	.235	.347	.256	.307	.111	.282	.365	.299	.422	.191	.355	.349
CZ						1	.511	.292	.350	.232	.235	.427	.399	.211	.380	.238	.300	.436	.375	.409	.078	.336	.486	.335	.378	.257	.377	.452
DE							1	.413	.403	.349	.310	.470	.507	.241	.389	.314	.374	.406	.354	.398	.082	.465	.506	.299	.273	.309	.340	.384
DK								1	.288	.227	.276	.300	.343	.151	.246	.241	.217	.252	.239	.272	.070	.329	.318	.188	.159	.304	.226	.229
EE									1	.223	.280	.335	.331	.152	.282	.221	.231	.337	.284	.424	.081	.233	.295	.177	.212	.249	.278	.260
ES										1	.157	.302	.281	.343	.251	.171	.336	.203	.160	.254	.047	.351	.246	.363	.150	.182	.233	.195
FI											1	.250	.285	.121	.159	.277	.206	.214	.170	.250	.099	.205	.258	.152	.121	.334	.160	.210
FR												1	.400	.219	.385	.247	.341	.351	.308	.371	.078	.355	.362	.277	.285	.253	.303	.378
UK													1	.217	.322	.342	.304	.303	.276	.375	.111	.382	.393	.250	.198	.315	.279	.297
EL														1	.183	.114	.269	.172	.169	.217	.109	.224	.193	.261	.153	.147	.191	.172
HU															1	.175	.219	.340	.209	.377	.051	.285	.332	.190	.400	.202	.333	.380
IE																1	.188	.209	.196	.226	.054	.251	.286	.152	.131	.162	.171	.173
IT																	1	.223	.245	.255	.080	.315	.294	.283	.171	.204	.257	.276
LT																		1	.245	.424	.029	.291	.503	.301	.378	.225	.250	.303
LU																			1	.284	.085	.234	.280	.202	.185	.154	.272	.256
LV																				1	.065	.320	.358	.238	.314	.269	.332	.332
MT																					1	.055	.050	.056	.045	.059	.073	.065
NL																						1	.386	.309	.216	.237	.313	.297
PL																							1	.344	.362	.256	.293	.328
PT																								1	.258	.157	.214	.189
RO																									1	.136	.306	.312
SE																										1	.175	.207
SI																											1	.318
SK																												1

Source: Authors' calculation based on the 8-digit ComExt trade data.

Table A1: Agri-food export structure similarity matrix in 2018/2019 on the EU-28 market.

	AT	BE	BG	CY	HR	CZ	DE	DK	EE	ES	FI	FR	UK	EL	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
AT	1	.046	.034	.010	.044	.024	.050	.023	.019	.034	.021	.061	.047	.028	.027	.015	.055	.027	.012	.021	.326	.045	.051	.027	.037	.021	.090	.026
BE		1	.102	.035	.131	.253	.288	.097	.098	.091	.053	.119	.142	.079	.067	.076	.108	.083	.079	.055	.026	.397	.184	.057	.087	.072	.063	.089
BG			1	.058	.209	.091	.098	.054	.023	.069	.024	.078	.046	.121	.040	.011	.078	.050	.019	.028	.003	.090	.088	.043	.133	.047	.068	.023
CY				1	.030	.033	.045	.027	.377	.084	.071	.039	.030	.069	.016	.028	.065	.115	.008	.017	.002	.035	.036	.057	.029	.020	.054	.017
HR					1	.131	.132	.041	.044	.090	.038	.096	.048	.089	.054	.027	.131	.077	.016	.048	.009	.059	.120	.077	.087	.049	.134	.205
CZ						1	.226	.088	.100	.091	.015	.074	.132	.043	.099	.062	.104	.026	.032	.029	.020	.245	.095	.041	.073	.102	.068	.136
DE							1	.156	.092	.150	.084	.152	.191	.089	.072	.109	.158	.146	.091	.074	.031	.259	.227	.069	.113	.112	.094	.116
DK								1	.029	.057	.081	.060	.113	.050	.071	.041	.064	.040	.023	.025	.021	.110	.182	.025	.051	.176	.033	.033
EE									1	.032	.131	.062	.094	.018	.017	.066	.032	.054	.025	.055	.005	.150	.088	.017	.019	.052	.012	.076
ES										1	.057	.135	.062	.285	.071	.038	.258	.060	.021	.032	.015	.109	.093	.274	.075	.043	.123	.050
FI											1	.057	.039	.016	.015	.093	.026	.065	.002	.197	.005	.088	.094	.017	.031	.207	.020	.184
FR												1	.146	.074	.056	.068	.193	.045	.040	.055	.018	.127	.109	.106	.090	.080	.143	.088
UK													1	.061	.042	.089	.108	.041	.039	.052	.038	.171	.105	.049	.051	.081	.062	.083
EL														1	.054	.018	.199	.039	.020	.027	.055	.084	.068	.195	.075	.040	.080	.033
HU															1	.026	.067	.019	.016	.017	.018	.053	.149	.037	.044	.021	.052	.074
IE																1	.044	.039	.030	.016	.008	.066	.043	.017	.019	.030	.022	.033
IT																	1	.053	.039	.051	.033	.095	.109	.190	.136	.074	.228	.114
LT																		1	.012	.073	.004	.068	.131	.030	.073	.035	.041	.026
LU																			1	.008	.014	.117	.020	.014	.017	.038	.036	.022
LV																				1	.003	.054	.142	.041	.037	.489	.022	.221
MT																					1	.054	.016	.002	.008	.011	.088	.049
NL																						1	.148	.055	.064	.100	.072	.115
PL																							1	.067	.070	.101	.068	.099
PT																								1	.059	.022	.094	.060
RO																									1	.071	.074	.065
SE																										1	.044	.231
SI																											1	.078
SK																												1

Source: Authors' calculation based on the 8-digit ComExt trade data.

Table A2: Agri-food export structure similarity matrix in 2018/2019 on the US market.

	AT	BE	BG	CY	HR	CZ	DE	DK	EE	ES	FI	FR	UK	EL	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
AT	1	.146	.067	.037	.075	.115	.407	.306	.140	.297	.312	.249	.220	.079	.244	.292	.138	.061	.077	.033	.015	.240	.371	.143	.128	.124	.206	.049
BE		1	.061	.022	.037	.119	.205	.096	.046	.113	.090	.179	.206	.042	.134	.110	.180	.067	.074	.077	.219	.147	.143	.243	.090	.104	.070	.064
BG			1	.040	.087	.084	.081	.023	.005	.064	.009	.055	.061	.085	.079	.021	.145	.006	.014	.024	.002	.040	.045	.084	.106	.059	.059	.079
CY				1	.024	.023	.030	.003	.012	.057	.001	.045	.023	.157	.038	.000	.068	.015	.013	.025	.020	.019	.021	.067	.044	.012	.044	.040
HR					1	.023	.147	.124	.005	.057	.009	.155	.064	.032	.077	.412	.087	.006	.283	.013	.001	.398	.105	.059	.100	.039	.045	.059
CZ						1	.110	.038	.041	.053	.048	.095	.093	.037	.215	.050	.117	.042	.040	.038	.024	.083	.174	.040	.171	.076	.036	.102
DE							1	.525	.032	.462	.253	.310	.325	.038	.295	.391	.136	.074	.169	.070	.061	.404	.285	.123	.122	.132	.197	.065
DK								1	.075	.467	.257	.265	.265	.013	.211	.309	.060	.028	.128	.009	.002	.370	.147	.136	.077	.077	.103	.021
EE									1	.046	.261	.042	.033	.005	.042	.061	.039	.157	.017	.347	.019	.033	.140	.056	.058	.062	.005	.002
ES										1	.230	.199	.234	.123	.276	.223	.199	.023	.036	.040	.034	.246	.057	.222	.111	.042	.177	.075
FI											1	.153	.161	.005	.154	.233	.051	.091	.011	.057	.002	.177	.202	.056	.084	.300	.106	.006
FR												1	.218	.071	.157	.291	.169	.079	.217	.030	.014	.288	.186	.140	.123	.074	.120	.076
UK													1	.031	.194	.225	.137	.048	.154	.074	.092	.295	.147	.182	.133	.104	.122	.068
EL														1	.039	.011	.270	.012	.014	.015	.010	.022	.034	.115	.097	.031	.063	.067
HU															1	.164	.150	.049	.044	.062	.048	.180	.171	.115	.135	.080	.172	.102
IE																1	.060	.046	.303	.010	.000	.642	.219	.087	.062	.086	.085	.010
IT																	1	.047	.061	.043	.024	.108	.108	.216	.205	.096	.123	.157
LT																		1	.007	.162	.023	.034	.063	.018	.076	.078	.007	.016
LU																			1	.021	.015	.311	.130	.033	.061	.049	.036	.021
LV																				1	.122	.032	.033	.053	.086	.102	.016	.016
MT																					1	.020	.017	.353	.026	.015	.004	.005
NL																						1	.182	.128	.091	.088	.105	.034
PL																							1	.039	.079	.152	.194	.047
PT																								1	.188	.029	.104	.121
RO																									1	.124	.189	.311
SE																										1	.033	.048
SI																											1	.143
SK																												1

Source: Authors' calculation based on the 8-digit ComExt trade data.

Table A3: Agri-food export structure similarity matrix in 2018/2019 on the Chinese market.

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A Strategic Analytics Using Convolutional Neural Networks for Weed Identification in Sugar Beet Fields

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Abstract

Researchers in precision agriculture regularly use deep learning that will help growers and farmers control and monitor crops during the growing season; these tools help to extract meaningful information from large-scale aerial images received from the field using several techniques in order to create a strategic analytics for making a decision. The information result of the operation could be exploited for many reasons, such as sub-plot specific weed control. Our focus in this paper is on weed identification and control in sugar beet fields, particularly the creation and optimization of a Convolutional Neural Networks model and train it according to our data set to predict and identify the most popular weed strains in the region of Beni Mellal, Morocco. All that could help select herbicides that work on the identified weeds, we explore the way of transfer learning approach to design the networks, and the famous library Tensorflow for deep learning models, and Keras which is a high-level API built on Tensorflow.

Keywords

Deep learning, CNN, precision agriculture, decision making, strategic analytics.

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Introduction

Today, companies can utilize machine learning or deep learning to help machines recognize the various aspects of agricultural production and help farmers enter the world of precision agriculture for making a decision (Fountas et al., 2006).

The sugar beet industry is one of the most important productive sectors in Beni Mellal region in Morocco (El Housni et al., 2020). A large area of 15,100 hectares was cultivated during the last agricultural season, which contributes around 26 percent of the national sugar production and plays an essential role in local economic development (El Bouzaidi et al., 2020). Successful cultivation of sugar beet depends mostly on weed control's efficacy during the first five to nine weeks after planting. It is known that the spread of weeds weakens the growth of sugar beets and hinders them from benefiting from the mineral salts necessary for better growth; therefore, weed control remains important for the increase in the productivity of the crops. Chemical control has become the most widely used means of controlling the spread of these weeds; this results in higher costs, pollution of soil and water resources. Besides, the herbicides may adversely affect the crops if applied in high concentrations, and then a frugal use of herbicides is desired (Jursik et al., 2020). So far, the common approach is the uniform application of herbicides to a field, neglecting the spatial variability of weed species and densities by mapping different species of weeds, their density and distribution; herbicide spraying can be adjusted as opposed to the uniform application.

This paper aims to use deep learning techniques to extract features from a set of collected images in order to classify in aerial images acquired; so we propose Convolutional Neural Networks (CNNs) for weeds detection (Jiang et al., 2020). We adapt and optimize our CNN model trained on our data sets and fine-tune with the five types of weeds most popular in sugar beet fields in the region; those weeds are stored in Kaggle public dataset (Hin, 2020). These approaches could be utilized as a part of a business-driven analytics strategy for agriculture organizations to develop visions and make a decision (Jabir and Falih, 2020).

CNN and Transfer learning approaches

Convolutional neural networks are the most powerful models for classifying images, also called CNN or ConvNet. They have two distinct parts. As input, a picture is provided in the form of an array of pixels. It has two dimensions for a grayscale image. The color is represented by a third dimension of depth, 3 to represent the fundamental colors [Red, Green, and Blue] (Bolo et al., 2019).

The first part of a CNN is the actual convolutional layer. It works as a feature extractor from images (Chen et al., 2016). An image is passed through a succession of filters, or convolution core, creating new images called convolution maps. The resolution of the image is reduced by a maximum local operation of some intermediate filters reduce. Finally, the convolution maps are flattened and concatenated into a vector of features called the CNN code (Albawi et al., 2017).

Convolutional neural networks are based on MLP (Multilayer Perceptron) and inspired by the behavior of the visual cortex of vertebrates. Although useful for image processing, MLPs find it very difficult to handle large images due to the exponential increase in the number of connections with the image size (Taud and Mas, 2018). In our example, we have an image with 98x98x3 size (98 width, 98 height, and 3 color channels), a single fully-connected neuron in the first hidden layer of the MLP would have 28812 entries (98 * 98 * 3) multiplied by the number of neurons would become enormous. A stack of independent processing layers forms a CNN architecture (Figure 1):

- CONV: The convolutional layer which processes the data of a receptive part.
- POOL: The pooling layer allows information to be compressed by reducing the intermediate image size (often by subsampling).
- RELU: The correction layer, frequently called by abuse 'ReLU', refers to the function activation (linear rectification unit).
- FC: The "fully connected" layer, which is a perceptron-type layer.
- LOSS: Loss layer.

Transfer learning is a process that facilitates learning from previous learning, provided there is compatibility between the two learnings (Zhuang et al., 2020). The typical use case of transfer learning is when the data are limited (a thousand photos of weeds) and where you learn from a neural network that has learned to recognize thousands of images (possibly involving different types of weed) classify weed species (Kartal et al., 2020).

Materials and methods

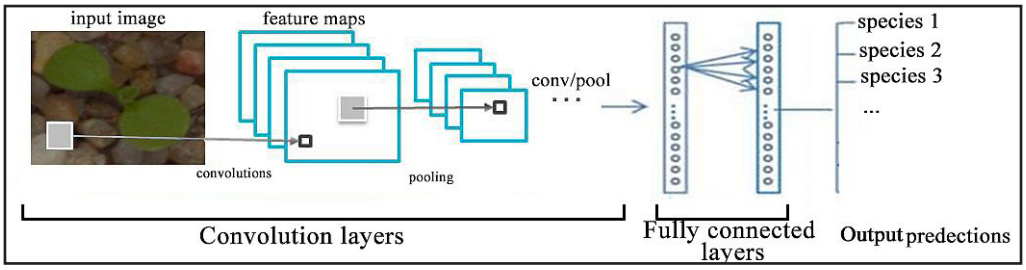
The data used for this study contain images of five different weed species well known in this region and spread in other parts of the world. In addition to the sugar beet pictures, to distinguish it from other herbs as shown below (Table 1).

Scientific name	English name	Moroccan name	Number of images
Beta vulgaris subsp	Sugar Beet	Chmander	463
Capsella	shepherd's purse	Kiss rai	274
Chenopodium	Fat Hen	Berramram	538
Galium aparine	Cleavers	Lassika	335
Sinapis arvensis	Charlock	kalkaz	452
Tripleurospermum	Scentless Mayweed	Kraa djaj	607

Source: authors

Table 1: A list of the weeds classes available for the study.

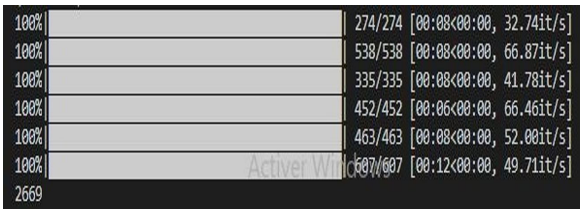
A digital camera (Sony a 6000) was used to manually collect our field images under different lighting conditions (from morning to afternoon in sunny and cloudy weather) from sugar beet fields of Fkihbensalh in Morocco. We combined these images with field images taken from an online repository Kaggle dataset (Analide



Source: authors

Figure 1: Standard architecture of a convolutional neuron network.

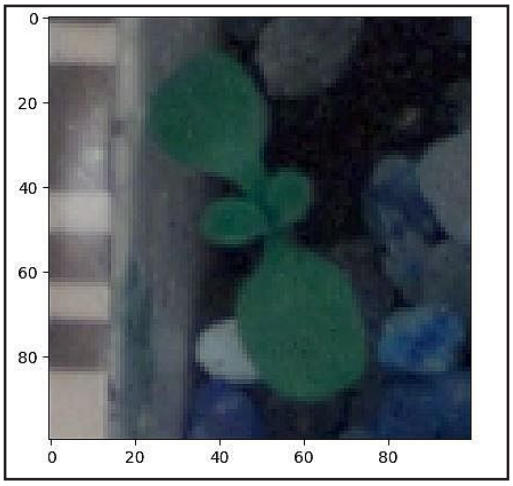
and Kim, 2017) to train the developed model, as shown in the following sections. We only use pictures of five harmful herbs that were strained in Beni Mellal area and added our images to them, in addition to pictures of sugar beet to get 2669 images in total belonging to six different classes (Figure 2), each class contains RGB images that show plants at different growth stages. The images are in various sizes and are in png format.



Source: authors

Figure 2: The six classes of the experiment.

Images in the training dataset had varying sizes. Consequently, images had to be resized before being used as input to the CNN model. Input images were resized to the shape of 98×98 pixels (Figure 3). Then created a path for each class and a variable that could store images in an array type (Figure 4).



Source: authors

Figure 3: Resized image.

```
[[ 86  84  86 ...  29  33  39]
 [109 105 106 ...  37  37  37]
 [135 135 134 ...  39  41  38]
 ...
 [158 157 155 ...  47  41  42]
 [158 157 157 ...  44  43  44]
 [158 157 157 ...  43  42  38]]
```

Source: authors

Table 1: A list of the weeds classes available for the study.

Implementation of CNN

This chapter defines the architecture of model that we created, and then we apply this model on images from our dataset. Thus, we work with python language for data science (Jarolímek et al., 2019), the Tensorflow and Keras libraries for learning and classification (Grattarola and Alippi, 2020). To improve the model's performance, we use some simple and effective techniques such as data augmentation and Tensorboard.

Tensorflow

Tensorflow is an Open Source programming framework intended for numerical computation made by Google in November 2015 (Goldsborough, 2016). Since its release, Tensorflow has continued to gain popularity and is becoming one of the most adopted frameworks for Deep Learning. Its name is notably inspired by the fact that the current operations on neural networks are mainly performed via multi-dimensional data tables, called Tensors. A two-dimensional Tensor is the equivalent of a matrix. Today, Google's main products are based on Tensorflow: Gmail, Google Photos, Voice Recognition.

Keras

Keras is a high-level neural networks API, written in Python, and can run on Theano or Tensorflow. It was developed with an emphasis on rapid experimentation, prepared to turn the idea into a result with the least amount of time. Keras was developed as part of the research effort of the ONEIROS (Open-ended Neuro Electronic Intelligent Robot Operating System) project, and its main author is a Google engineer called François Chollet (Chollet and Allaire, 2018).

In 2017, the Tensorflow organization at Google decided to support Keras in the Tensorflow core library. Chollet explained that Keras was created as an interface rather than an end-to-end learning environment. It presents a higher-level, more intuitive set of abstractions that make it easy to configure neural networks independently from the backend computer library. Microsoft is also working on joining a CNTK backend to Keras as well (Chollet, 2018).

Python

Python is an interpreted and object-oriented high-level programming language with dynamic semantics (no compilation step). It emerged as a popular language used a lot in data science

applications; take the case of the tech giant Google that has created a deep learning framework called Tensorflow (Nagpal and Gabrani, 2019).

This language is the first used for creating those frameworks' reusability of codes. Python and its libraries are available in source or in binaries free for most platforms and could be redistributed for free.

The architecture of our initial CNN model

As shown in Figures 5 and 6, during our experiments, we created a basic model. It is composed of two layers of convolution, two layers of Maxpooling, and two fully-connected layers (Abd El-Rahiem et al., 2019).

The input image is 98*98 size; the image goes to the first convolution layer (CONV). This layer is composed of 256 filters of size 3*3, the activation function ReLU (Rectified Linear Units) is used; This function ($F(x) = max(0,x)$) forces the neurons to return positive (Agarap, 2018). After this convolution, 256 feature maps of size 98*98 are created. Maxpooling (POOL) is applied afterward to diminish image size and settings. At the exit of this layer, we have 256 feature maps of size 49*49. We repeat the same thing with convolutional layer number two (composed of 256 filters). The ReLU activation function is always applied to each convolution. A Maxpooling layer is deployed after the convolution layer number two at the output, and we have 256 feature maps of size 23 * 23. The vector of characteristics resulting from the convolutions has a dimension of 135424.

Next, we use a neural network made up of two fully connected layers (FC) (Basha et al., 2020). The first layer has 64 neurons, and the second layer is a Softmax, which allows us to calculate the probability distribution of our classes (six classes in the dataset) (Figure 5 and 6).

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 98, 98, 256)	2560
activation (Activation)	(None, 98, 98, 256)	0
max_pooling2d (MaxPooling2D)	(None, 49, 49, 256)	0
conv2d_1 (Conv2D)	(None, 47, 47, 256)	590080
activation_1 (Activation)	(None, 47, 47, 256)	0
max_pooling2d_1 (MaxPooling2	(None, 23, 23, 256)	0
flatten (Flatten)	(None, 135424)	0
dense (Dense)	(None, 64)	8667200
dense_1 (Dense)	(None, 6)	390
activation_2 (Activation)	(None, 6)	0

Total params: 9,260,230
Trainable params: 9,260,230
Non-trainable params: 0

Source: authors

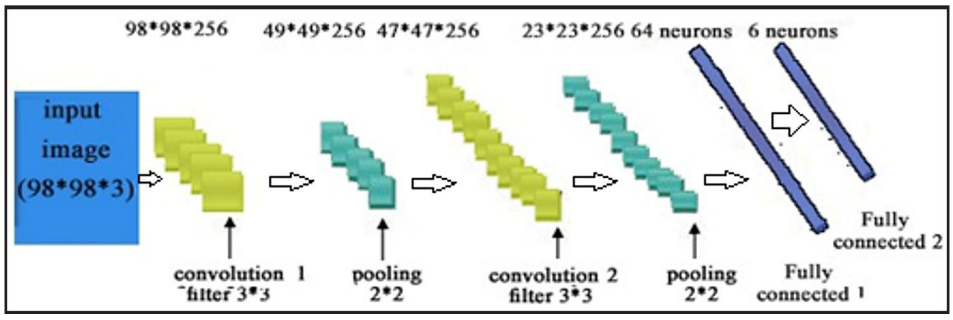
Figure 6: Model's configuration.

Results and discussion

There are several parameters employed for evaluating the performance of the classification and prediction models. Accuracy and error are some of the metrics for evaluating the performance of classification models (Nakzawa and Kulkarni, 2018). Accuracy is defined as follows:

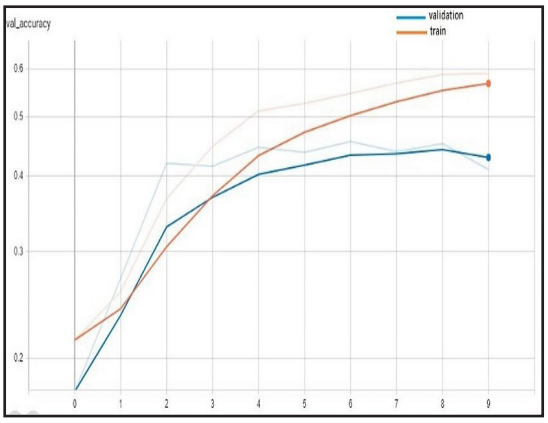
$$Accuracy = \frac{number\ of\ correct\ predictions}{total\ number\ of\ predictions}$$

Classification error relative number of misclassified examples, in other words, the percentage of wrong and incorrect predictions (Khaki et al., 2020). In order to show the results obtained for our model, we illustrate the results in terms of accuracy and error in the next section (Figures 7 and 8).



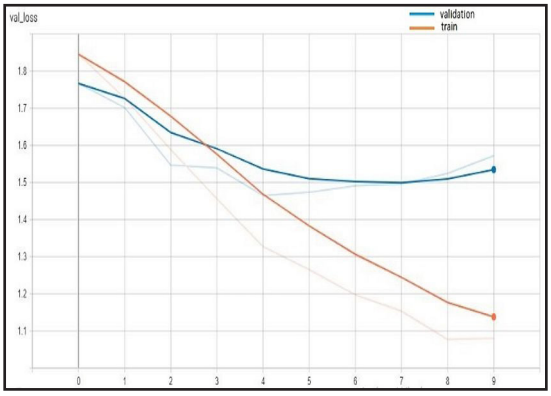
Source: authors

Figure 5: Model's architecture.



Source: authors

Figure 7: Model's precision.



Source: authors

Figure 8: Model's error.

After analyzing the results obtained, the following remarks are noted:

According to the previous two figures, the accuracy of the learning increased with the number of epochs. This reflects that in each epoch, our model learns more information to reach 73% accuracy. However, it eventually begins to fall after the 8th epoch. This should alert us that we are almost certainly starting to overfit (Xu et al., 2019). The reason why this happens is that the model is constantly trying to decrease in-sample loss. At some point, the model begins just to memorize input data instead of learning general things about the actual data, which means any new data we attempt to feed the model will perform poorly. Likewise, the learning and validation error decrease with the number of epochs, and after the 8th epoch start to rise. Thus, we will need more information to teach our model. Therefore we have to look for a solution that reduces overfitting, thus increasing the number of epochs and modifying other parameters, which is the object of the next sequence.

Optimizing the model

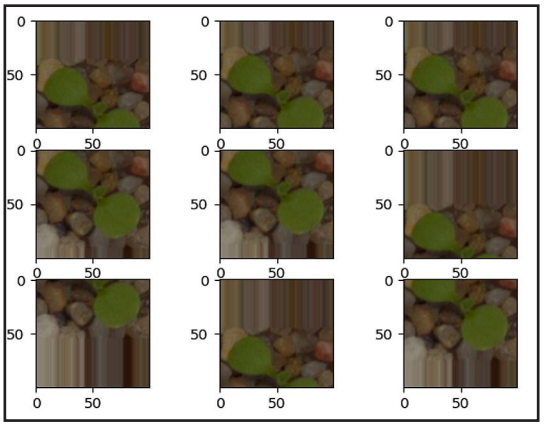
After some epochs, we have 73% validation accuracy, but we should probably discuss how we can optimize this model to improve this value. As we discussed in the previous sequence, we need to reduce overfitting, and for that, there are a lot of solutions. We quote five techniques (Data Augmentation, Regularization, Early Stopping, Simplifying the Model, Dropout) (Kim and Kang, 2020). For our case, we will focus on the data-augmentation solution. Also, we will use Tensorboard, which is a powerful application that comes with Tensorflow. It helps us visualize our models as they are trained and build a workflow to optimize our model's architecture.

Data augmentation

Data augmentation is a powerful technique that can reduce overfitting in Neural Networks, where we increase the number of training data using information only in our training data. This is done by applying domain-specific ways to examples from the training data that create a large amount of data (new and different training examples) (Hand et al., 2018). A variety of methods are supported, we focus on our model on five main types of data augmentation techniques for image data specifically:

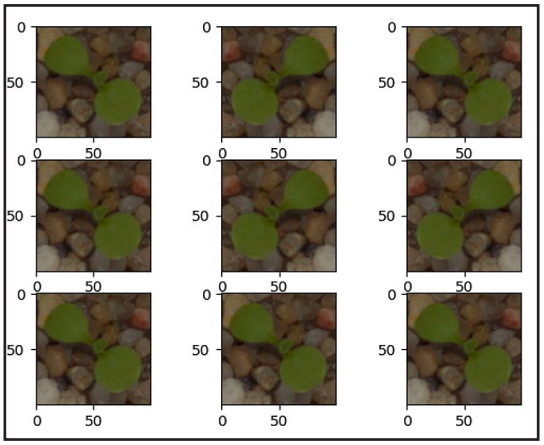
- Image zoom argument: *zoom_range*.
- Image shifts Arguments: *width _shift_range and height_shift_range.*
- Image rotations argument: *rotation_range*
- Image flips arguments: *horizontal_flip and vertial_flip*
- Image brightness argument: *brightness_ range.*

The following figures (Figures 9 and 10) are examples of two techniques used in our data augmentation. The first is vertical shifts of the image via the *height_shift_range* argument; in this case, we specified the percentage of the image to shift to 0.5 the image's height. The second example is an augmenting of the chosen image with horizontal flips via the *horizontal_flip* argument.



Source: authors

Figure 9: Images with a random vertical shift.



Source: authors

Figure 10: Images with a random horizontal flip.

Tensorboard

Convolutional neural networks, however, have several parameters to adjust. The most basic things for us to modify are layers and nodes per layer and 0, 1, or 2, dense layers, and other parameters like varying layer sizes, learning rates, and activation functions. Thanks to the python code, we create a loop that allows us to assemble and test a set of combinations (80 combinations) (Figure 11) and choose the best of them, which gives good results (high accuracy visualized on Tensorboard application (Luus et al., 2019) (Figure 12).

```
dense_layers = [0,1,2,3]
layer_sizes = [32,64,128,256,512]
conv_layers = [1,2,3,4]

for dense_layer in dense_layers:
    for layer_size in layer_sizes:
        for conv_layer in conv_layers:
            NAME = "{}-conv-{}-nodes-{}-dense-{}".format(conv_layer, layer_size, dense_layer, int(time.time()))
            print(NAME)
            model = Sequential()
            model.add(Conv2D(layer_size, (3, 3), input_shape=X.shape[1:]))
            model.add(Activation('relu'))
            model.add(MaxPooling2D(pool_size=(2, 2)))
            for l in range(conv_layer-1):
                model.add(Conv2D(layer_size, (3, 3)))
            ...

            for _ in range(dense_layer):
                model.add(Dense(layer_size))
                model.add(Activation('relu'))
            ...
```

Source: authors

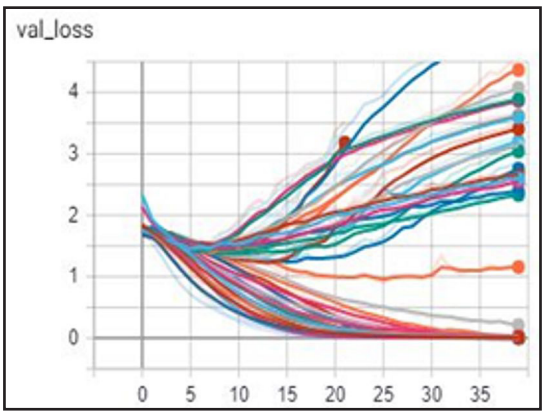
Figure 11: A part of python code, which forms the combinations.

```
1-conv-32-nodes-0-dense-1599243547
2-conv-32-nodes-0-dense-1599243547
3-conv-32-nodes-0-dense-1599243547
4-conv-32-nodes-0-dense-1599243547
1-conv-64-nodes-0-dense-1599243547
2-conv-64-nodes-0-dense-1599243547
...
3-conv-256-nodes-3-dense-1599243547
4-conv-256-nodes-3-dense-1599243547
1-conv-512-nodes-3-dense-1599243547
2-conv-512-nodes-3-dense-1599243547
3-conv-512-nodes-3-dense-1599243547
4-conv-512-nodes-3-dense-1599243547
```

Source: authors

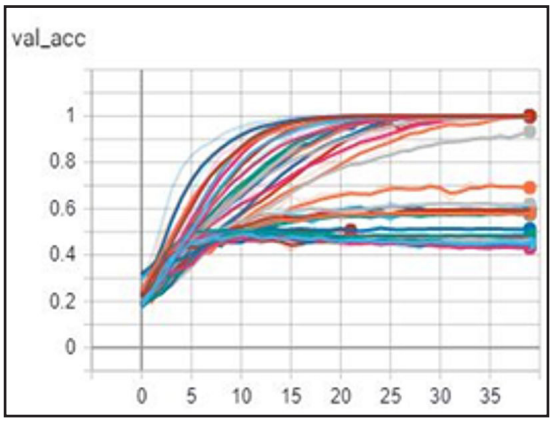
Figure 12: Set of 80 created and tested combinations .

The figures (Figures 13 and 14) below captured from Tensorboard show a visualization of the 80 models created above. We could be tempted to take the highest validation accuracy model, but instead, we tend to go for the lowest validation loss models in the resulting graph. Therefore, zooming into the validation accuracy graph or validation loss graph allowed us to choose and check some of the best models.



Source: authors

Figure 13: Error of the generated models.



Source: authors

Figure 14: Accuracy of the generated models.

After zooming into the graph (Figure 15), here are the top 3 models have the highest accuracy. We can be satisfied with 0 dense, and 1 convolutional layer, and 128 nodes per layer.

Source: authors

Figure 15: Top three models with the highest accuracy.

Changing some parameters, using a model with data augmentation technique and choose 0 dense, 1 convolutional layer and 128 nodes per layer, with more epochs (40), had developed the precision to 82% of accuracy with 20 hours of training (Figure 16).

```
----------------
84/84 [==============================]- 11s 127ms/step -loss: 0.5166 - sparse_categorical_accuracy: 0.8277
----------------
Test accuracy: 0.8276507854461670
----------------
```

Source: authors

Figure 16: Test accuracy of the optimized model.

Also, increasing the number of pictures can increase the model's accuracy, knowing that there is no specific number of model training images, but previous experiences affirm that when we have more images, we will have more accuracy. According to the results discussed above, the experiments have demonstrated good achievement in optimizing and training our CNN model to address weed classification with limited training images. But there are always limitations which can be cited as follows:

- The resolution of training images poses some restrictions due to memory requirements.
- The models trained in images where the weeds are in determining size have difficulties in detecting the weeds when the size is significantly different.
- The optimization with Tensorboard consumes much time and resources.
- Developing systems that can take pictures that will be used to determine the percentage of weeds and their spread still requires deep scientific research.

Conclusion

Our objective was to create and optimize a CNN model able to detect and identify the percentage and the species of weed most popular in this area, with high accuracy. That could promote the frugal use of herbicides and control the spread of these weeds. In the proposed work, we created a CNN model that can classify images from a large dataset. This model gives an accuracy of 82% after a set of processes that help improve precision and decrease error. Indeed, the model is primarily focused on species common to the studied region (weeds that are in the dataset), but since it has reached a good accuracy, we can feed the dataset with other vegetation, and obviously, it can give good results.

Further steps may be taken to improve the accuracy and evaluate the model with other parameters in the future. Also, we need to try to find a solution to the real-time image capturing and combine it with our CNN model as a powerful real-time weed-crop classification and technical localization for robotic weed control.

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NB-IoT Sensor Network for Obtaining the Input Data for Hydrological Simulation Model

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Abstract

The article describes the choice of appropriate network technology that provides sufficient coverage to allow the sensor network to be placed even in the remote and difficult to reach locations and the data to reach the cloud server. Further it describes the components of the sensor network, the operating principle, architecture and the processing of the data obtained to convert them into the input data used in the hydrological simulation model. The NB-IoT sensor network proposed by the authors would not only collect the data needed to operate hydrological simulation models, but, for example, could provide the data needed to forecast weather conditions, particularly if the architecture of this sensor network, because of its low cost, would be widely applied around the globe, joining a unified global sensor network.

Keywords

Sensor network, internet of things, IoT, sensor data processing, NB-IoT.

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Introduction

The need for real-time access to weather data helps in monitoring and facing the escalation in the frequency and intensity of potentially dangerous events as drought, heavy rainfall, flooding and extreme temperatures (Idbella, et al., 2020). These data are also useful for operating simulation models, which allow to understand causal relationships in order to minimise the effects of human activity on the environment.

As an example, we can mention that after construction of drainage ditches, thus changing its natural hydrologic regime, many bogs in Latvia have been degraded, leaving a negative impact also on the adjacent unaffected and slightly affected hydrological regime of raised bogs and other wetlands. After drainage, bogs and its adjacent forest areas became overgrown with trees. The large volume of tree crown by interception prevents rainwater from reaching the ground, because it evaporates back into the atmosphere, as well as trees favor water absorption from the soil through the roots that further enhance the drainage effect. To restore degraded bog, first of all, it is necessary to fill up drainage ditches, but if the bog is overgrown by trees, this action may not be enough and it is indispensable to cut down part of the trees. Experimentation with forest thinning intensity in real life would take years to establish the optimal scale of intervention into the ecosystem (intensity of thinning out in order to reach the desired result by cutting down as few trees as possible) to increase saturation of soil with water that would contribute to resurgence of the bog and swampy forest biotopes. Hydrological simulation models can help to solve this issue. The available hydrological models are a simplified reflection of reality, which is useful and works sufficiently accurately in large-scale modelling but unable to accurately display all the water flows of the specific bog ecosystem, which are vital in regional-level models (O'Keffe, et al., 2019; Staes, Rubarenzya, Meire and Willems, 2009). To deal with issues faced by existing hydrological models a new model specifically designed to simulate the bog hydrology was developed during previous research (Java, 2018). This

model allows predicting the tree cutting influence on the ecosystem without expensive and time-consuming experiments in real life (Java, 2018). Since the model is designed for regional modelling, so that its simulated output data is as accurate as possible, input data must also be accurate and thus collected in situ. Of course, the combination of simulation models and the proposed NB-IoT sensor network can be applied in different ecosystems to address other, different issues as well.

An IoT sensor network proposed by authors is expected to operate similar as an automatic meteorological station, but its main advantages will be that it will not need cable connection to the electrical network or the Internet, it will be compact and relatively inexpensive.

Currently, several IoT networks are operated in many locations and the coverage is growing. Choosing the appropriate IoT connectivity option for a specific need is fundamental (Ismail, Kassim, Ismail and Mohamad, 2018). There are several LPWAN (Low Power Wide Area Network) networks available in Latvia. Company Tet emphasizes that it was the first company operating the first IoT network in Latvia (tet, 2020) from 1st July 2017, which uses LoRa network technology (kursors.lv, 2017). Another company that offers IoT network solutions in Latvia by using Sigfox network is 0G Baltics (0G Baltics, 2020). One of the current weaknesses of LoRa and Sigfox technologies to support IoT solutions focused on environmental simulation and modelling is their coverage which covers only the largest cities in Latvia, leaving rural areas uncoated (tet, 2020) (Sigfox, 2020). LoRa and Sigfox coverage only in the largest cities is confined to the use of these technologies, which is a remote reading of different utility meters, which does not require high service quality and stability, as is the case with a IoT meteorological station where the data must be read several times a day instead just once a month. Unlike LoRa and Sigfox, NB-IoT (NarrowBand IoT) technology specified in Release 13 of the 3GPP in June 2016 can coexist with GSM (global system for mobile communication) and LTE (long-term evolution) under licensed frequency bands (Mekki, Bajic, Chaxel, & Meyer, 2018). NB-IoT technology is able to use existing mobile network infrastructure, which has coverage throughout Latvia. LoRa and Sigfox uses unlicensed ISM bands (Mekki, Bajic, Chaxel and Meyer, 2018), and because NB-IoT uses licensed spectrum bands (just like 3G and 4G) it isn't significantly affected by interference (Vodafone Group, 2017) and intervention from outside. To provide guaranteed quality of service, NB-IoT endpoint devices consume additional energy because of synchronous communication (Mekki, Bajic, Chazel and Meyer, 2017; Iqbal, Abdullah and Shabnam, 2020). Taking into account the previously mentioned, and that the NB-IoT network provides 1 MB of data volume transmission per month with 64 Kb/s data transmission speeds throughout the territory of Latvia using secure data transmission connection (Latvijas Mobilais Telefons, 2020), it can be concluded that the most appropriate IoT network in Latvia circumstances is NB-IoT, provided by Latvia Mobile Telephone (LMT).

Materials and methods

This article is based on literature research to find the best way to build an IoT sensor network to collect the input data for simulation models.

It can be said that there is no need to install new sensors in order to gather and store meteorological data, since different climate data services are operated, for example on the Copernicus satellite base. The atmospheric reanalyses (ERA5) of the European Centre for Medium-Range Weather Forecasts (ECMWF) dataset was produced on behalf of Copernicus Climate Change Service (C3S) and was generated entirely within the Climate Data Storage (CDS) Toolbox (ECMWF, 2020). This historical dataset might seem suitable for hydrological modelling, but if we talk about modelling related to a specific point, such as a bog, its resolution in the 0.5 x 0.5 degree grid (ECMWF, 2020) is not sufficient. Satellite precipitation products still suffer from quantitative uncertainties and biases compared to ground data (Pellarin, et al., 2020), but parameterizations and adequate initialization of outputs from hydrological models is limited due to lack of sufficient in situ data (Ndehedehe, 2019).

Sensors that collect meteorological data for hydrological simulation modelling often need to be placed in locations away from any infrastructure so they can detect any changes in the environment and notify the user of any events that have occurred. Then these daily changes need to be captured and uploaded to the cloud server so the user could then use it to get the periodical data from sensors.

IoT owes much of its success to the widespread distribution of Internet communication networks (Idbella, et al., 2020). Leading mobile operators, global vendors and developers are launching NB-IoT network as an integral part of their long-term 5G IoT strategies (GSMA, 2018). NB-IoT is

an innovative network dedicated entirely to the IoT. This network is public and uses existing LTE cells, the same ones that were used for GSM mobile phones years ago (Idbella, et al., 2020). IoT sensors are low cost, use low data volumes, require long battery lives and often operate in remote and hard to reach locations. Mobile IoT delivers connectivity on a massive scale today and will continue to do so in the 5G future (GSMA, 2018). With the IoT new business models can be built, new services offered or efficiency increased (Deutsche Telekom AG, 2019). In the context of the hydrological model, IoT sensors would increase efficiency, as compared to the standard meteorological station. The IoT sensor network would use a significantly lower amount of data transmitted and electricity consumed.

The NB-IoT network standard is a genuine game changer to IoT solution providers, as it expands the technical possibilities to make massive IoT deployments economically feasible (Deutsche Telekom AG, 2019). NB-IoT is an open standard based on LTE. It has the backing of major equipment manufacturers, and is based on familiar technology for easier integration into existing infrastructure and processes (Vodafone Group, 2017).

The NB-IoT technology can work with lower signal strength compared to GPRS technology (Deutsche Telekom AG, 2019) and as it uses licensed spectrum bands (just like 3G and 4G) it is not significantly affected by interference (Vodafone Group, 2017). Due to these facts, NB-IoT network is suitable for environmental monitoring in remote places where signal coverage is problematic.

There are many ways to reduce power usage and achieve long battery lifespans. Most simply, you can keep the device in idle mode or deep sleep, so it doesn't waste power chatting to the network between communication sessions. Power management is fundamentally a balance between message frequency, device sleep cycles and business case needs (Vodafone Group, 2017). Because an IoT battery can serve up to 10 years (assuming equivalent of two AA batteries and typical pattern in base coverage cell) (Deutsche Telekom AG, 2019), the question arises whether, given that technology is changing rapidly, it is worth investing in this technology. NB-IoT is a Third-Generation Partnership Project (3GPP) standard closely related to LTE technology, as a result, it can be deployed on almost all LTE base stations, alongside LTE traffic, through a straightforward software upgrade to the radio access network (RAN), it gives the reassurance that it is a low-risk, long-term technology (Vodafone Group, 2017).

Results and discussion

Meteorological sensor networks are data-centric networks, which process data for continuous meteorological data collected by sensors (Yang et al., 2019). In order to collect the input data required for the simulation model of the hydrological regime, the sensor network must obtain groundwater level measurement (mm) and meteorological data such as precipitation in form of rain or snow (mm), wind speed (m/s), solar radiation (W/m^2), air temperature (^oC), relative humidity (%). If the modelling was performed in a geographically larger area as an average Latvian bog and there were several such sensor networks, it would also be important to gather information on the wind direction as well.

Sensor network components

Many parameters, such as average daily air temperature, are currently easy to calculate because measurements can be automatically performed at a short time interval (once every 0.25 seconds (Met Office College, 2020)), stored digitally, and divided by the amount of measurements with the number of measurements. In author`s view, this method does not correspond to the nature of IoT sensors, one of the main advantages of which is the ability to place them in remote and/or difficult-to-reach areas to measure and transmit data in a way that consumes as little energy as possible to extend battery life. Publication describing studies of IoT meteorological sensors often use a 3-hour interval between measurements (Liu et al., 2018), or a 10-minute interval based on correct measurement records (Awandallah, Moure and Torres-González, 2019). In the rest of the chapter, authors describe the choice of IoT sensors and their provisional operating principle, which would allow one to find a balance between the frequency of measurements, consumption of energy and amount of data transferred.

Radio modem and antenna

A radio modem with an antenna is required so that all sensors can be integrated into a single system, controlled and data can be transferred. Because of the open code hardware and software, authors have chosen Arduino`s ecosystem as the most suitable for a radio modem and antenna solution. For example, the SODAQ SARA AFF R412M developer board compliant with IoT standard Arduino formfactor is suitable. It has a powerful 32 bits microcontroller, 256 KB flash memory, two grove sockets to easily connect any sensor, two JST connectors to connect battery and solar

panel, onboard charge circuit, accelerometer, GPS, NB-IoT and antenna. When connecting a battery and SIM card to the developer board, it becomes a modem that is capable of operating autonomously and does not require manual intervention. As NB-IoT supports bi-directional communication where orthogonal frequency division multiple access (OFDMA) is used for downlink, and single carrier frequency division multiple access (SC-FDMA) is used for uplink (Chaudhari, Zennaro, & Borkar, 2020), the updates can be done remotely by connecting from the workstation.

Battery

Mobile IoT radio modem usually draws bursts of current for a short time, also called pulse currents (Texas Instruments Inc., 2020) to hundreds of milliamps in a matter of tens of microseconds (Tektronix, 2015). A battery needs to be dimensioned to deliver such currents also in potentially extreme temperature conditions (very cold or hot environments). On the other hand, one has to consider the battery self-discharge and the capacity loss during storage. For a battery lifetime estimation, several other factors should be considered, e.g., cut-off voltages, battery efficiency, leaking currents, temperature effects etc.

In order to achieve very long battery lifetimes and reduce maintenance cycles for IoT applications, it is recommended to use primary lithium chemistries such as SAFT LS 26500 3.6 V Primary lithium-thionyl chloride (Li-SOCI2).

Groundwater level

Groundwater level measurements can be performed with two types of IoT sensors, a water pressure sensor such as SEN0257 DFROBOT or a laser distance sensor such as OKY3240-1 OKYSTAR. In both cases, it is necessary to drill holes in which to insert the shells to create wells. In the case of a pressure sensor, it must be placed at the bottom of the well and the groundwater must be calculated by the water pressure, which varies depending on the weight of the water above it. If a laser sensor is used, it must be attached to the well cover, a floating surface must be placed in the water for the determination of the distance to the surface of the water.

The hydraulic conductivity of acrotelm (top layer of peat soil up to depth of approximately 50 cm) is 330 cm/day, but is rapidly decreasing from 9 cm/day at depth of 1.2 m to 0.16 cm/day at a depth equal to or greater than 2 m (Custers and Graafstal, 2005). Given the hydraulic conductivity of acrotelm and the presence of drainage ditches in degraded bogs, fluctuations in groundwater can reach several tens of centimetres within one day, so the author recommends that groundwater measurements be performed at the same interval as the last measurements (excluding the amount of precipitation) to obtain the average daily value, as the simulation model generates output data as the daily value.

Mean air temperature and relative humidity

Statistical tests shall indicate that the measurements have been made at a lower interval, the more accurate the average daily temperature value. In order to find a balance between the number of measurements and the life of the battery, authors identified the Mannheimer-Hour method as the most appropriate method to determine the average daily value, which can be expressed by the Kämtz`schen equation:

$$TM = (T07 + T14 + 2 * T21) / 4$$

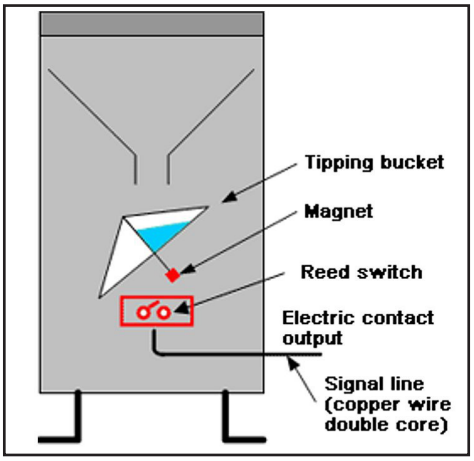
Where TM is the average daily air temperature, $T07$, $T14$ and $T21$ denotes the air temperature at 7:00, 14:00 and 21:00 respectively. A double weight is assigned to the temperature at 21:00 for the average air temperature to be as precise as possible (Behrendt and Zimmermann, 2008). A very low proportion of variation R2 0.99 with RMSE 0.06 was observed when comparing the average daily temperature values of the air temperature calculated from data with a reading interval of 4 times per second and Mannheimer-Hour method using only three readings per day.

Since relative humidity is closely associated with air temperature due to the amount of water vapour in the air, expressed as a percentage of the maximum amount of steam that the air could hold at the given temperature (Yahia, 2019), authors suggest that, for measurements of relative humidity Mannheimer Hour method with R2 of 0.95 is applicable. To measure air temperature and relative humidity, such as the integrated temperature and humidity IoT sensor Grove SHT31 with typical accuracy of ±0.3 °C for temperature and ±2% error for humidity is appropriate (Seeed Technology Co., Ltd., 2020).

Precipitation

Precipitation gauges are used in meteorological stations that capture rainfall through the funnel, deliver it to special buckets in which they are weighted, read, and sent to the server as shown in Figure 1. Such equipment is not suitable for the IoT sensor network as it requires constant electricity supply and electric heating during

a period of negative air temperature. Since a funnel-type rain gauge is unable to determine the type of precipitation, only the amount of precipitation in millimetres should be relied on either the air temperature (positive or negative) or the additional microwave radar should be added to determine the type of precipitation.



Source: Furukawa Electric Co., LTD, 2011

Figure 1: Precipitation gauge.

Laser precipitation sensors such as OTT Parsel2 LUFFT are available on the market. For this distrometer, laser technology provides an opportunity to calculate type, amount, intensity and kinetic energy of the precipitation (Lufft, 2020). By exploring the range of IoT laser sensors available, the authors found no one capable of measuring both the size and velocity of the falling particles at the same time, by which it would be possible to calculate the amount of rainfall in millimetres, so an alternative method was sought.

According to authors, the best way to create an alternative IoT distrometer is to use a precipitation sensor, such as OKY3435 OKYSTAR, which generates a signal 0 or 1, as a switch that, depending on the presence of absence of precipitation, would turn on or off a low power doppler microwave radar BGT24LTR11, which would perform measurements until a signal with value of 0 would be received from the precipitation sensor. In order to further reduce the battery consumption, cloud technology allows the system to connect one of the online weather forecasts, such as the national portal meteo.lv/laiks, which, when precipitation is not forecast, turns off the precipitation sensor, but when precipitation is forecast, turns it into standby mode.

Wind speed

For wind speed measurements, it is necessary to select an IoT anemometer, such as SEN0170 DFROBOT, which consumes little energy and generates an output signal with a voltage from 0 to 5 V. The wind speed is determined according to the voltage output curve from 0 to 30 m/s (DFROBOT, 2020). Given that wind can give gusts, wind speed is set to be the mean of two-minute measurements (National Weather Service, 2020). This means that, in order to obtain the daily wind speed, measurements should be made once an hour over a two-minute period of 0.25 second interval, the mean value for each hour should be calculated and the daily mean values should be divided by the number of hours.

Solar radiation

The hydrological simulation model developed by Java (2018) uses solar radiation in the equations that calculate the transpiration of the forest stand and the melting of snow. In addition to solar radiation, transpiration is also affected by other meteorological conditions such as: air temperature, wind speed and atmospheric humidity deficit (difference between saturated water vapour pressure and actual water vapour pressure). The melting of snow, excluding solar radiation, is affected by air temperature.

Solar radiation measuring instruments are expensive. From the 31 automatic observation stations located on the territory of Latvia, only 7 have measuring instruments installed, measuring total solar radiation in Watts per square meters (Valsts Vides ģeoloģijas un meteoroloģijas centrs, 2020). Several sources mention that approximately 6% of total solar radiation reaching the Earth's surface is UV radiation (Gharehpetian and Mohammad Mousavi Agah, 2017; Jacobsen and Dangles, 2017), therefore, given that solar radiation is not the only meteorological factor affecting transpiration and melting of snow, the author proposes that IoT UV sensors, such as Grove I2C UV light Sensor VemL6070, to be used for solar radiation measurements.

To reduce the electricity consumption, the author proposes to connect a light sensor, such as SEN0043 DFROBOT, to the sensor network, which would measure the light intensity once an hour. Shortly after sunset and before sunrise, the light intensity is 10 lx (Schlyter, 2017), so this is assumed as a reference value, because when it is exceeded, the sun is visible on the horizon, so radiation

from it reaches the Earth together with the light. Above 10 lx the light sensor instructs the UV sensor to take the measurement. Daily measurements must be made until the light intensity drops to 10 lx and must be counted together and corrected by a factor of 16.7 to obtain a result close to total solar radiation.

Sensor network body

In order to protect the modem and the battery from external climatic conditions, an airtight junction box has been used, which is available in any hardware store. One rain sensor holder printed out with a 3D printer was attached to the junction box, allowing the rain sensor to be installed at an angle of 45 degrees so that the water could easily drain from it and allow the sensor to dry quickly after the precipitation has ended. The second rain sensor holder was used to attach UV and light sensors at an angle that prevents snow from accumulating and blocking the sunlight. A solar radiation shield was printed out with a 3D printer and installed under the junction box to protect temperature and relative air temperature sensors. An anemometer was attached to the top of the junction box. To facilitate 3D printing, the authors used the templates available on thingiverse.com.

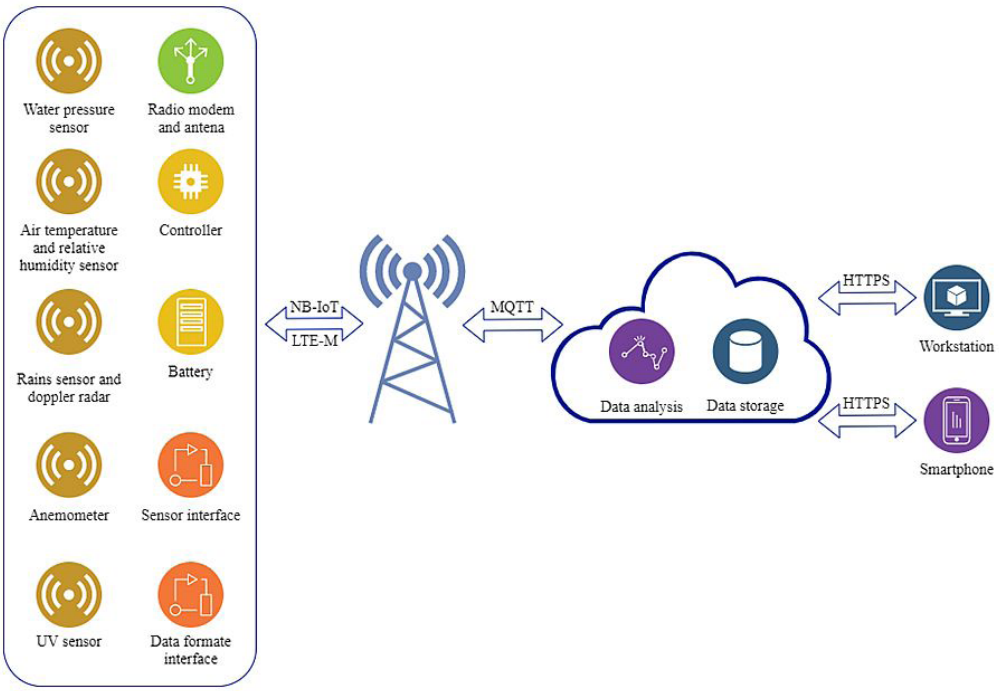
Sensor network architecture

NB-IoT sensor network architecture (see Figure 2) consists of sensors, controllers, sensor interface, data format interface, batteries, radio modem and antennas described in the previous section, which together form a sensor network.

Sensors are integrated into a single system and placed in the selected remote location and are connected to the radio modem. The architecture uses NB-IoT network to transfer data from device to mobile cell tower. Using the MQTT protocol, data from a mobile cell tower is transferred to the data cloud where they can be stored and analysed. In the cloud, raw data is decoded into measurement data. The modem allows the modeller to interact with the devices attached to it. Once the communication mode is set up and the cloud server is configured, the communication takes place between sensors and the cloud server. The architecture provides that the modeller can access data stored in the cloud using the Internet browser and, if necessary, remotely change the interface between the sensors and the data format.

Meteorological data storage

The authors believe that sensor network data should



Source: Authors

Figure 2: NB-IoT sensor network architecture for obtaining hydrological simulation model input data.

be stored in a data storage located in the cloud. Cumulocity has been a leading application enabling platform and IoT management platform since its launch in 2010 (i-SCOOP, 2020). Cumulocity includes all tools and capabilities needed to manage IoT sensor network through the cloud:

- Secure connection;
- Device management;
- Self-service analytics;
- Rapid enterprise application integration;
- Tools to accelerate smart product development;
- Advanced analytics tooling for data experts;
- Lifecycle of machine learning models management (Software AG, 2020).

Once the sensor network is registered on the Cumulocity IoT platform, it is necessary to change the communication interval to 24 hours, minimizing the intervals for sending information to the cloud and back, while defining it so small that it is possible to identify errors and resolve them in a timely manner. This is important in order not to lose data for a longer period of time, as it can be in the case when the sensor network is installed in a remote location and left to operate independently there. If there had been a failure, the researcher would only find it out when visiting the site to read the data.

Raw sensor data can be downloaded in a CSV and Excel file that stores the data as shown in Table 1.

Data can be downloaded from the Cumulocity IoT platform separately for each sensor. The authors uses the Stella Architect model for simulations, whose input data is uploaded via single file in CSV format, so it is important that the data are formatted in the way that the simulation model supports.

Python script was designed and developed to process sensor data from the Cumulocity IoT platform to appropriately format input data for the simulation model. The script determines which Cumulocity IoT user account must be logged in, which sensor data for which time period should be collected, what mathematical steps should be taken to calculate average daily values, how to store data in the CSV format of the simulation model, to which email address data should be sent.

Python script runs on the server of the Vidzeme University of Applied Sciences. If the simulation model itself had been developed in Python script and located on the same server, it would be possible to upload the data to the simulation model without email, which would allow real-time simulations, only to change a few lines in the data processing script. An example of how the input data generated by the Python script to the CSV file is shown in Table 2.

A new data point with an average measurement value is created in the input data file for each subsequent day. New types of measurements can be added to the table by adding new columns, but attention should be paid to the fact that the column names must match the names of the converters defined in the simulation model, otherwise it will not be able to recognize the data and store them in the corresponding converters.

The Python data processing script contains several values that can be configured as needed, for example, the recipient's email or data sending period from seven days to a shorter or longer time as needed can be changed.

In order to make the data collected by the sensor network publicly available, it is intended to publish the processed data to the Latvian Open Data Portal (data.gov.lv) in the future or a similar international site, as well as to use the data uploaded to the portal of other users to supplement the data collected by the sensor network, providing an opportunity to build new simulation models and knowledge.

time	source	device_name	fragment.series	value	unit
2020-08-01T09:00:26.563Z	1940	MQTT Device sodaq001	Humidity.Relative Humidity	52	%RH
2020-08-01T14:00:44.644Z	1940	MQTT Device sodaq001	Humidity.Relative Humidity	43	%RH
2020-08-01T21:00:10.598Z	1940	MQTT Device sodaq001	Humidity.Relative Humidity	58	%RH

Source: Authors

Table 1: Cumulocity raw data output.

Date	Average Temperature	Average humidity
01.08.2020	17.92	52.75

Source: Authors

Table 2: CSV file of input data generated by Python script.

Conclusion

The low cost of IoT sensors and the NB-IoT network data technology, small size and long battery life open up opportunities for wider acquisition of high-quality in-situ data that can be used for simulation models. While, based on cloud computing algorithms, it is not possible to create a single global meteorological data repository with a sufficient resolution to make the data available and usable to operate high precision local simulation models, IoT sensor networks are suitable for obtaining these data and could become part of a global sensor network in the future. A sensor system that collects input data for the hydrological system dynamics model has the potential to use machine learning techniques to calibrate sensors, to look for faulty sensors, to know in advance that maintenance is required and to predict future weather forecasts if needed.

Other IoT sensors and developer boards similar to ones offered by the authors can be used to collect in-situ data to support hydrological models with input data taking into account the proposed architecture and working principles. The exception is the microwave doppler radar for which no alternative was available on the market during the development of the sensor network. The proposed architecture of the sensor network for data collection was tested by a field campaign during the last year and results of this campaign show effectiveness of data collection and data transfer by existing NB-IoT network. Collected data from this campaign were successfully used in the simulation and model results show adequate coverage of input data for running defined simulations.

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Barriers to and Benefits of the Use of Smart Farming Technologies for Small and Medium Winemakers, Specifically Sensors and Weather Stations: A Pilot Study

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Abstract

Digitization is becoming part of agriculture. Winemakers can use monitoring technologies to map land or control the quality of grapes, and telematics, e.g., in tractors, or use entire autonomous machines. The aim of this paper is to find out the barriers to and benefits of the use of smart farming technologies by small and medium winemakers, specifically sensors and weather stations, which allow the collection of site-specific data for subsequent application in viticulture. Therefore, the pilot study analyses how winemakers in traditional industry are able to employ smart farming technologies (SFT) to gain some benefits and also describe possible barriers. The primary method of data collection was through 27 semi-structured interviews with relevant wine industry actors, accessing documents created by SFT providers and an academic literature review. Three groups of actors were researched: 1) 22 winemakers including the Ekovin Association, 2) three SFT providers and, 3) one supplier of hardware for soil and temperature sensors. According to the information of winemakers, it is clear that SFT are used by some of them and they are clearly aware of their benefits, which is also confirmed by SFT providers. The findings revealed that the main STF benefits are adjustment of the product portfolio, savings, consulting and organization of activities. However, respondents also mentioned barriers to SFT implementation, such as low need for information, another source of information, conservative approaches, ignorance of SFT, financial demands, low state support and age of winemakers. The novelty of this paper is in providing an analysis of the issue of SFT, specifically sensors and weather stations, for winemakers from three different perspectives, that of winemakers, suppliers of SFT and HW manufacturer for SFT.

Keywords

Smart farming technologies, precision agriculture, precision viticulture, winemakers, Czech Republic.

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Introduction

As in industry, digitization is also becoming part of agriculture. Precision agriculture (PA) is a relatively new discipline in agronomy. Developed in the mid-1980s, it has been listed among the top ten agricultural enhancements in recent decades (Crookston, 2006). Farmers use smart farming technologies (SFT), which make farming processes more data dependent. Thanks to these technologies, it is possible to increase the accuracy of inputs to crops and soils based on the environmental context and specific needs of the site. The global agricultural industry is constantly seeking to maximize its concerns' economic, environmental and qualitative benefits. Secondly, modern automation for effective agro-production is still not used by most sectors. Smart technologies have presented new and innovative ways for optimized agriculture via an automated system of environmental parameter monitoring. Viticulture, for example, is a highly delicate process in which mesoclimate and soil conditions are inherent; thus, checks and efficient quality control of the process is essential (Voutos et al., 2018). Four modes of SFT can presently be distinguished in accordance with Fountas et al. (2015): (1) recording and mapping technologies, which collect site-specific data for further application, (2) tractor GPS and associated tools that apply variable rates of inputs as appropriate

and accurately guide tractors via real-time kinetics, (3) apps and farm management and information systems (FMIS) integrated and linked with mobile devices to offer easier farm monitoring and management, and (4) machines which operate autonomously (e.g., weeding and harvesting robotic systems).

How can SFT help winemakers produce better harvests? Generally, winemakers rely on more advanced weather forecasts, but in the past also on the knowledge of older winemakers, who remembered the weather conditions for each slope of a vineyard. Unfortunately, the latter situation has not been the case for some time due to climate change and/or human intervention. The weather is simply harder to predict than in the past, and winemakers need the most accurate data possible. The solution is a small weather station, which is located in a vineyard and can measure temperature, humidity, precipitation and calculate, for example, a dew point (Průžek, 2019). This data is sent at regular intervals via the network to the server and the winemakers receive a relatively accurate forecast, or just the data measured, on their mobile phone or via the web interface on the computer. The data should be accurate enough to predict impending frosts. Thanks to this technology, winemakers can prevent the growth of basic pathogens with a significantly lower use of chemicals (Průžek, 2019).

Precision viticulture

Precision viticulture (PV) is a relatively new discipline, whose development started in the 1990s (Sentesban, 2019). Some scholars use other designations such as smart viticulture or Viticulture 4.0. In this paper precision viticulture (PV) will be used. PV technologies have more recently enjoyed a rapid evolution and superior applicability because of reduced costs, ease of use, and versatility. These innovative solutions' benefits regarding their application is generally in the form of financial savings in crop management, and greater ecological sustainability due to the rationing of chemicals used in farming (Matese and Di Gennaro, 2015). The fast pace of information communication technologies and geographical science provides for PV huge potential for the advancement of optimized solutions for the dissemination of information. PV therefore strives to utilise the broadest range of observations at hand to outline in high resolution a vineyard's spatial variability. It further seeks to offer suggestions for the improvement of efficiency of management relating to quality, production, and sustainability (Matese and Di Gennaro, 2015).

The implementation of PA techniques into viticulture, i.e., the development of PV, occurred significantly later than was the case in other crops. Research and commercial applications in PV only commenced in the mid-2000s (Santesteban, 2019). The reason for this delayed adoption was not apathy on the part of wine growers, but rather difficulties inherently associated with vineyard characteristics: discontinuous canopy usage and the organization of vines in rows require higher resolution images to distinguish canopy from soil, and superior computing capacity for the management of vineyard spatial information before being used (Matese et al., 2015). Recent technological developments have seen the enhancement of tools to aid in the monitoring and control of many parts of vine growth. Remote and proximal sensing sensors have become substantial resources for the determination of vineyard status, such as water and nutrient availability, plant health and pathogen attacks, or soil conditions.

Smart Farming Technologies in precision viticulture

SFT used in PV are divided into two main categories. The first one focuses on monitoring technologies, which form the foundation of spatial variability mapping. The second discusses technologies used in the provision of site-specific agronomic inputs, classified as variable rate technologies (VRTs) and "agbot" systems (Matese and Di Gennaro, 2015). The acquisition of the maximum possible amount of georeferenced information within the vineyard is the primary goal of the monitoring process. A broad range of sensors seeking to monitor various parameters which characterize the plant growth environment are utilised in PV for remote and proximal monitoring of geolocated data. The three systems employed most frequently in remote sensing are satellites, aircraft, and unmanned aerial vehicles (UAVs), each using different application methods and sensors (Matese and Di Gennaro, 2015). VRT in PV permits agronomic management to be differentiated and the inputs dosed in terms of time and space. Software programs within the technology have the ability to combine the positional information, obtained by a GPS module, with prescription maps created for each specific operation (Escolá et al., 2007). The application of agronomic inputs is therefore no longer derived as average quantities per hectare, but instead according to the actual requirements of the vines ascertained

from the vineyard heterogeneity. Automation technologies are used in modern agricultural machinery to control movement within the vineyard, relating to velocity and direction of travel and steering angle, and further to oversee agronomic operations. An automatic guidance system based on the use of GPS and proximity sensors is viable due to the presence of advanced board technology (Vieri et al, 2013). This article focuses only on the first area (monitoring technologies, which form the foundation of spatial variability mapping) and is considered from three different perspectives, that of winemakers, suppliers of SFT and HW manufacturers for SFT.

The use of robotics in PV currently remains at the prototype stage, but a great deal of these projects is already close to completion, with some already available on the market (Matese and Di Gennaro, 2015). However, there are some current examples of robot implementation. Château Clerc Milon winery from Bordeaux, France, is one example of where a robot has been used, its value coming from its collecting of data directly at the vineyard and this data's subsequent evaluation, which is then easily transferred to the winemaker's computer or mobile phone. Moreover, it can assist with general farm work, such as the spraying or pruning of shrubs. The Spanish VineScout robot project is another example of robotic data collection of vine growth. It was granted European Union funding and commenced in August 2019. These are not breakthrough technologies unseen in other sectors, but their existence is proof that very traditional industries, such as viticulture, are beginning to deploy them (Strouhal, 2020). In Napa Valley, California, at the Palmaz winery, big data is similarly used to produce the most optimal bottle of wine, according to owner Christian Palmaz. His Vigor system (conjunction with Filics software) combines sensors, probes and X-rays in the collection of millions of data units, which subsequently serve as an alert to various diseases or determine optimal harvest time and grape storage, as well as helping to produce great quality wine (Strouhal, 2020).

Smart Farming Technologies in precision viticulture in the Czech Republic

Similar technologies have also already been implemented by some Czech SFT providers, e.g., by the Czech startup Agdata, which is building an information platform combining IoT sensors and other data from farms as well as from the fields themselves. It is not focused directly on viticulture, but it can be also used for winemakers (Strouhal, 2020). AG data offers everything for PA in one system, namely business management, sensors, machine monitoring, satellite imaging, legal records, leases. Its system allows easy planning of crops, field work, property management or, for example, automatic recording of activities. It draws important data from the agricultural registers of the Farmer's Portal and ČÚZK and is closely connected to many physical devices such as GPS or wireless sensors, which provide you with real-time telematics of your machines or information about warehouse conditions (Agdata, 2020). Clever Farm has developed an application that offers all the principles of modern agriculture in one. Their platform delivers a sustainable, cost-effective and automated way of farming. The company focuses on four areas, namely: agroevidence, sensors, PA and soil registration. Its products can be applied to various parts of the world, from small family farms to large companies owning tens of thousands of hectares (Cleverfarm, 2020). This company provides a soil sensor, which measures the humidity and temperature at the depth of insertion of the sensor. A moisture absorption sensor was used to measure the water potential of the soil, which eliminates influences that could skew the measurement and does not require calibration on the soil type and chemical composition. The sensor will help to optimize irrigation and determine the appropriate planting time. The sensor is either on a pole or on buried wires (Cleverfarm, 2020).

The Czech "Smart Vineyard" project (Chytrá vinice) uses small-sized, new generation weather stations which record temperature, humidity and rainfall data. As a result, they provide winemakers with information on temperature, dew points, precipitation and local conditions relating to the occurrence of the pathogens Vine fungi, Vine powdery mildew and Botrytis cinerea. All information is displayed on the winemaker's computer or directly on their smartphone. 31 winemakers and 78 smart vineyards are involved in the project, with the equipment involved already on the market for four seasons (Chytrá vinice, 2020). Another new interesting project is DynaCrop API, which is being developed by the World from Space company. It can help to obtain instant access to agriculture related information for any location in the world and company products can increase the field yields and reduce inputs to save money for its customers.

The company provides services such as a single observation map (anytime), time series graph, field zones, smi (DynaCrop, 2020).

There are also other companies which are more local providing SFT, such as AMET - sdružení Litschmann & Suchý (AMET), which map pests, temperatures, precipitation and prepares information from weather stations and other information (Amet, 2020). Mr. Litschmann is the author of many articles published in various magazines and proceedings, which are mainly focused on the processing of information from weather stations, such as wind conditions in wine regions of the Czech Republic in 2019.Concurrently, some wine associations, such as Ekovín, are enthusiastic advocates of using data from weather stations as well. Ekovín brings together winemakers and winegrowers engaged in integrated production and organic production of grapes and wine. It publishes weekly on its website and sends its members an email with a Monitoring Report on the occurrence of harmful organisms in vines in South Moravia, which provides important information about possible pests, as well as temperature and precipitation (Ekovín, 2020).

iNELS, a product of ELKO EP, has existed since 2007, when it was one of the first pioneers in the Czech Republic to develop and manufacture intelligent wiring for houses and buildings called Smart Home & Building Solutions (iNels, 2020). In agriculture its products can be used on farms, greenhouses, apiaries or in forests and pastures. On farms, SFT can safely monitor via motion sensors and a camera system, as well as significantly help save energy through lighting control. In fields, sensors and weather stations can monitor the status of conditions in production areas. Products provide information on temperature, air and soil humidity, precipitation, wind strength and direction, which can be displayed via applications on a computer or smartphone (iNels, 2020).

There are a large number of smart agriculture platforms abroad, such as The SmartAgriFood Accelerator, which is supporting SMEs developing smart services and apps to be addressed in the agri-food sector or Smart Farming Thematic Network, which is open to farmers, SFT solution providers or researchers.

Related works

In order to improve comprehension of the relevance of current technological progress in European farming systems, 287 farmers were surveyed in seven EU countries and in four cropping systems. Of the farmers interviewed, around 50% had utilised SFT and 50% had not. Out of 287 farmers, 66 were wine growers, 24 of whom were SFT adopters and 42 were non-adopters. Farm size positively correlated with adopter numbers, and adopters in arable cropping systems outnumbered those in tree crop and vineyard farming (Kernecker et al., 2020). López-Leyva et al. (2019) presented the design and field tests of a system to remotely monitor environmental variables in a vineyard in the Guadalupe Valley, Mexico, which was done with early-adopters to find out the performance of the prototype. Dorofeeva et al. (2019) mention that the systems of parallel driving, informatization and monitoring, mapping of yield and differential fertilization are implemented in precision farming in Russia. The costs of fuel, seeds, fertilizers, and chemical means of protecting crops are reduced by using these technologies. Similarly, Caffaro and Cavallo (2019) also found a low uptake of both investigated technologies a) SFT Type 1, which involves technologies investigated, the management information systems, such as drones, sensors for data acquisition and automatic download, and agricultural apps and b) SFT Type 2, which involves in-field advanced working tools technologies such as agricultural robots and autonomous machines, and tractors equipped with CAN-bus, which is an electronic system connecting components of the tractor (engine, transmission, hydraulic system), implements (seeder, fertilizer spreader, etc.), and sensors (typically GPS positioning systems), even though those who participated in the research stated that in daily life they used ICT regularly. It is therefore crucial that the ICT options most useful to farmers are identified in order to be able to convey how these targeted agricultural interventions can benefit their operations. This will be crucial in closing the gap between those farmers who willingly use ICT in their daily lives but are more reticent about using SFTs in their professional work. Martini et al. (2020) present a systematic mapping of studies that use prediction and context awareness in agriculture. Their findings showed that 35.7% of the studies used one or more prediction techniques, 45.2% used image processing through pictures of cameras to get information regarding planting. They found 23 sensors with different functionalities in agriculture.

Drivers, benefits and barriers of SFT

The main drivers for the implementation of precision farming not only in Russia, but throughout the world, are maximizing

the harvest, financial benefits, minimizing capital investments and minimizing the impact on the environment (Dorofeeva et al., 2019). However, winemakers' general views on SFT and their experience with them is a key driver in whether they believe they need to use weather stations. Kernecker et al. (2020) present the five most important reasons for the use of SFT in agriculture as follows: SFT are helpful for agriculture; SFT improve on previous tools; SFT improve work processes and workload; SFT use sees an increase in productivity and work comfort. New technologies ensure to lower production costs between 20 and 30 % which would be helpful for winemakers (Proffitt, 2015). Cost reduction is mainly coming from optimising the utilisation of water, fertilizers, fungicides and also from working efficiently in the vineyard (Advanced Technologies for Industry, 2017). The claim that SFT would reduce a farm's impact on the environment, that SFT can improve farm intake and decrease farm pollution was, however, the most disputed by farmers (Kernecker et al., 2020). GPS-related technologies are most significant to arable farming; mapping and recording tools, which are able to track weather events, for example, have greater worth in horticulture and viticulture, where yields and income per hectare are more impacted upon by microclimate or plant diseases (Kernecker et al., 2020).

Kernecker et al. (2020) also note that the adoption of STF may be inhibited by certain factors. Reasons for not adopting SFT: high investment costs; too complex to use; inappropriate technology in relation to the farm context and size; the added benefits of SFT are unclear, a situation not improved by live demonstrations of SFT use with a neutral advocate not being accessible to farmers. Barriers for those who do adopt SFT are as follows: high investment costs; difficulty of interpreting data; no interoperability between devices and a lack of precision; added benefits are unclear and neutral advice is again lacking. In addition, it was stated by both farmers and experts from all sectors across Europe that the cost–benefit and added value were not clear and that insufficient infrastructure, such as weak broadband connectivity, also prevented SFT adoption, alongside a lack of current information and high costs, is an important determiner of access to SFT (Kernecker et al., 2020).

Current literature available focuses mainly on arable farming and respective technologies (e.g., GNSS based technologies), which subsequently and generally serves larger farms in north-western EU nations better than smaller farms in other states (Kernecker et al., 2020). Consequently, this necessitates an increased research focus on small farmers, such as winegrowers, from regions beyond that of the north-western EU. As Kerneker's et al. (2020) comment, mapping and recording technologies are the more relevant SFT type for orchards and vineyards. Therefore, the research was focused on SFT which can be used in viticulture. The aim of this paper is to find out the barriers to and benefits of the use of smart farming technologies by small and medium winemakers, specifically sensors and weather stations, which allow the collection of site-specific data for subsequent application in viticulture. In order to fulfil the aim of the paper, three research questions have been researched:

RQ1: Do small and medium winemakers use SFT, specifically sensors and weather stations?

RQ2: What are the benefits of the use of SFT by small and medium winemakers, specifically sensors and weather stations?

RQ3: What are the barriers to the use of SFT by small and medium winemakers, specifically sensors and weather stations?

To find out the answers to these research questions, a combination of surveys of winemakers, SFT providers in viticulture and supplier of hardware for sensors was used, so that the issue was processed from complex perspectives.

Materials and methods

Manufacturers combine servitization and digitisation, but academic research in this field has only taken place quite recently (Raddats et al, 2019). Even among farmers, SFT are beginning to be used successfully and, in some regions and areas, SFT are almost a matter of course. However, in general, agriculture is still perceived as a traditional and rather conservative sector. Agriculture is the oldest sector of the economy and after a period of consolidation of technologies from 1990 to 2000, it has experienced a spectacular evolution under so-called Precision Agriculture (PA) (Caffaro and Cavallo, 2019). Technological innovations are changing mechanisation in agriculture. The introduction of modern ICT in the agricultural sector is necessitated by the ever-growing demand for food and farm products. The agricultural industry is not the origin of Industry 4.0, as it is considered

one of the least digitized industries overall, but the potential of advanced manufacturing methods has been recognized across all sectors (Gandhi et al., 2016). However, no research has focused on the use of SFT, specifically sensors and weather stations, by winemakers from complex perspective, i.e., from the point of view of winemakers, suppliers of SFT or HW manufacturers for SFT.

To learn more about SFT used by winemakers, the empirical part of the research included a) interviews with winemakers, b) interviews with SFT providers, including those in winemaking and c) interviews with HW manufacturers of SFT. To find out more about this topic, a combination of surveys was used, so that the issue was processed from complex perspectives. Surveys were conducted in the form of semi-structured interviews. The areas of interview issues were partially inspired by the previous research of the author of this paper, which was held in small and medium electrotechnical companies in 2017–2018. The interviews with winemakers targeted the following areas: basic information about winery; type of SFT; the reasons for the commencement of SFT provision; the benefits gained from SFT; possible barriers to implement SFT and using the data gained from SFT. The interviews with SFT providers and interviews with HW manufacturers for SFT targeted the following areas: type of SFT provided for winemakers or for SFT providers; the length and manner of SFT provision; customer segmentation; customer perception of SFT; the reasons for commencing SFT provision; the benefits gained from SFT; barriers connected to SFT provision; gathering and usage of the data gained from SFT; specifics of the Czech market; collaboration with other firms in SFT development and future plans. For this paper, only relevant areas from interviews related to the aim of the paper (description of winemakers and SFT providers, the benefits gained from SFT and possible barriers to implementation of SFT) were selected and described.

Sample and data collection

The Czech Republic has two wine regions, Moravia and Bohemia, divided into six subregions. There are 383 wine villages and 18067.93 hectares in 1,313 vineyards. These are managed by 18,399 growers. Most vineyards (96%) are located in Moravia, with the remaining 4% in Bohemia. Of the total area, 70% is planted with white grape varieties. There are over 1000 registered wineries, from large companies to small family businesses (Wine regions of the Czech Republic, 2019). The largest expanse of vineyards is in the Velkopavlovická Wine sub-region. The fertile lowlands, which stretch from Brno to Židlochovice, Hustopeče, Velké Bílovice and Velké Pavlovice, belong among the sunniest places of the Czech Republic (Wine regions of the Czech Republic, 2019). According to the Czech Statistical Office, the consumption of grape wine (fruit wine is not included) has increased by almost half since 1989. From the original 11.3 litres per person in 1989, it climbed to 16.9 litres per person in 2016. According to the Winegrowers' Association, wine production in the Czech Republic has fluctuated around 600,000hl per year in recent years. Consumption is above 2.1 million hl. About three quarters of the wine drunk is therefore imported to us (Nevyhoštěný and Chripák, 2019).

To answer the research questions, the surveys were prepared in order to map complex views, namely those of SFT providers to the winery, suppliers of HW for SFT providers and winemakers where SFT adopters and SFT non-adopters were included. The respondents were recruited from owners and top managers (in-depth interviews with SFT providers and HW suppliers) and from owners or managers (interviews with winemakers). The primary method of data collection was via 26 semi-structured interviews with relevant wine industry actors, accessing documents created by SFT providers and an academic literature review. Three groups of actors were researched: 1) 22 winemakers including the Ekovín Association of ecological wine growers and winemakers, 2) Three SFT providers (AG data, Clever Farm and Chytrá vinice – Smart vineyard) and 3) One supplier of hardware for soil and temperature sensors (ELKO EP). The sample covers all of the three actor types operating in this market.

Interviews with winemakers

For this pilot study examining the use of smart products in viticulture, the small and medium-sized winemakers were only from the Velkopavlovická Wine subregion, which is one of the six wine regions in the Czech Republic. Those in the small winery category produce up to 50,000 litres a year; those in the medium viticulture category produce 5,000 to 250,000 litres a year; those in the large winery category produce over 250,000 litres a year (Vinařství roku, 2020). Respondents from viticulture were selected on the basis of purposive sampling according to the list of members of the Union of Winemakers

of the Czech Republic. In addition, snowball sampling (Coleman, 1958) was used, when the process began with the suppliers of SFT for viticulture, who suggested some winemakers who were already using SFT. This type of sampling is cost and time efficient (Kemper et al., 2003). Interviews lasted 20 to 30 minutes and were held in September and October 2020. The interviews were done mainly via online calls through Skype or Google Meet and in ten cases via email when the list of questions was sent directly to the winemakers. The total number of winemakers included in the survey is 22, where nine winemakers were SFT adopters, 12 winemakers were SFT non-adopters and one was the Ekovín Association.

Interviews with SFT providers and SFT suppliers of hardware

In order to broaden the view of the issue, the most important SFT providers (including SFT for viticulture) in the Czech Republic were also contacted. These included CleverFarm, Agdata and Chytrá vinice (Smart vineyard), who were selected after a thorough website study. Even according to the winemakers, themselves, who were participants in the research, all the main actors of SFT provision in this business were addressed in the research. Also, one supplier of hardware for soil and temperature sensors (ELKO EP) was included in the research. Interviews lasted 30 to 60 minutes and were held in October 2020. The interviews were done during online calls via Skype or Google Meet.

Data analysis

Interviews were mainly recorded and transcribed. About 14 categories related to benefits of SFT were extracted from the initial research, of which an analysis was made in order to ascertain which were similar and which were different. Reduction of the number of codes then took place, resulting in the number of first-order categories becoming eight. Aggregate themes of a more abstract nature were then determined through analysis of the first-order categories. This process yielded three agglomerated themes labeled Savings, Consulting and Organization of activities. The final coding structure is shown in Table 3. The benefits of SFT by winemakers and for barriers related to SFT by SFT providers and winemakers was subjected to an identical procedure (Table 2, Table 4 and Table 5). As qualitative case research is sensitive to researchers' subjective explanations, some peer consultation was needed to avoid researcher bias and to ensure greater objectivity in the study. A rich set of direct interview quotations to demonstrate interpretations was added to support the transparency and conformability of the findings.

Results and discussion

The pilot study analyses how winemakers in traditional industry are able to employ SFT to gain some benefits or how they struggle to implement them. The findings to RQ1 – RQ3 are presented below along with some quotes which help to illustrate the findings.

RQ1: Do small and medium winemakers use SFT, specifically sensors and weather stations?

The total number of winemakers included in the survey is 21, where nine winemakers (43%) were SFT adopters and 12 winemakers (57%) were SFT non-adopters (see Table 2). However, Ekovín also prepares the documents for the Monitoring Report for their members. This document is sent to them weekly and it is also uploaded onto the Ekovín website. The Monitoring Report is prepared by Ekovín on the basis of its own experts and some member companies. Ekovín also cooperates with CleverFarm, Chytrá vinice (Smart Vineyard) and AMET.

	Small winery	Medium winery	Total
SFT Adopters	4	5	9
SFT Non-adopters	8	4	12
Total	12	9	21

Source: Author

Table 1. SFT adopters and SFT non-adopters which participated in the surveys.

Of the SFT Adopters, four are small winemakers and five are medium-sized winemakers, which is an almost identical result. A bigger difference can be seen in SFT non-adopters, where eight of them are small winemakers and four are medium-sized winemakers (see Table 1). SFT providers who participated in the research offer farmers (including winemakers) the following products: a) IoT sensors and weather stations that monitor irrigation, pests, precipitation, temperature, leaf wetting. Based on mathematical models, they predict development and inform users about the status of pests in three colors: green - no problem; orange - checking required; and red - necessary intervention of spraying, B) satellite data - biophysical parameters from the satellite, which show where the largest yield is and divide the land into five zones to manage the fertilization process,

c) agroevidence - records of fertilizers, sprays, seeds, which are a necessary legislative component and d) records of land and lease agreements. According to SFT providers, winemakers use area a) and c) the most, with a predominance of sensors and weather stations.

According to SFT providers, their customers are from all categories of winemakers - from micro winemakers to large wineries. But their typical customer is an older winemaker who hands over his winery to a younger one, such as a father and son, or a young agronomist at a larger winery who is about 30 - 40 years old. These younger winemakers have a closer relationship to SFT. However, it's not always about age, even older winemakers choose to use SFT. However, all SFT providers clearly agree that in recent years the situation has shifted greatly (thanks to gradual generational change) and improved for SFT, and it is only a matter of time before most winemakers will perceive the benefits of these SFT.

"Our service can be used for 12/24/36 months and then it is possible to terminate it, but it hasn't happened yet."

"SFT have been an important topic in the world for a long time, there is less interest in them in the Czech Republic. However, even here they have become a sexy topic."

"Czech agriculture is well modernized, such as modern tractors, machines, but there is a lack of digitization and interconnection of systems at farmers. Several of the largest agribusinesses have a digitized agenda (such as fuel), but there is a lack of connection between individual agendas. Small businesses have nothing, sometimes they have software for wages, agricultural records, such as fertilizer records, but nothing complex."

To sum it up, winemakers are increasingly starting to use SFT, especially sensors and weather stations in their wineries. SFT adopters are rather younger winemakers (30 - 40 years) who have a closer relationship with SFT and have information about their use and possible benefits. Confirmation of interest in SFT is also shown by Ekovín activity, which regularly informs its members on a weekly basis about environmental monitoring.

RQ2: What are the benefits of the use of SFT by small and medium winemakers, specifically sensors and weather stations?

Winemakers perceive the main benefits of using sensors and weather stations in the following items: time savings, financial savings and adjustment of the product portfolio in line with changing climatic conditions. The main two benefits are savings and consulting. The final coding structure is shown in Table 2.

First-order categories		*Aggregate themes*
Time savings	→	Savings
Financial Savings	→	
Adjustment of the product portfolio in response to changing climatic conditions	→	Adjustment of the product portfolio

Source: Author

Table 2. STF benefit categories by winemakers.

According to STF providers and HW supplier, the benefits of using sensors and weather stations were the following: saving time; saving petrol; saving costs of fertilization; irrigation; spraying; saving personnel; advice on what to do; which pests to target; help with drought; when and how much to water. The benefits were additionally seen in the overview of the use of one system, where all the important information will be held. The main three benefits are savings, consulting and organization of activities. The final coding structure is shown in Table 3.

First-order categories		*Aggregate themes*
Time savings	→	Savings
Saving gasoline		
Saving costs of fertilization, irrigation, spraying		
Personnel savings		
Advice on what to do	→	Consulting
Advice on pests		
Help with drought, when and how much to water		
Have everything organized in one system	→	Organization of activities

Source: Author

Table 3. STF benefit categories by STF providers and HW supplier.

CleverFarm also features case studies on its website that show financial savings when using their SFT. According to them, it is very suitable for helping potential customers to realistically understand what their solution can bring them.

"Smart technologies are currently key for us in deciding on economic interventions, which affects economic efficiency. According to the information, the use of SFT requires a combination of experience / knowledge and quality data from these technologies."

"For micro-winemakers, it is certainly a great advantage of the information obtained from the weather station, whether it is necessary to go to the vineyard today or not."

"For large wineries, the advantage is definitely some help with the organization of work, when they have large areas of vineyards. The solution will advise them where they need it today and where tomorrow."

"Thanks to SFT, we are able to adjust the planting of suitable varieties, based on temperature information within the year."

"Declining rainfall and climate change are forcing winemakers to be effective. There is also state pressure starting to save water and sprays."

RQ3: What are the barriers to the use of SFT by small and medium winemakers, specifically sensors and weather stations?

Winemakers perceive the main barriers to using sensors and weather stations in the following items: low need for information; traditional approaches; ignorance of SFT, which means no awareness of SFT, no experience and ignorance of SFT benefits; financial demands and another source of information. The final coding structure is shown in Table 4.

First-order categories		*Aggregate themes*
They do not need to measure a lot of parameters	→	Low need for information
They don't need information		
They have their proven approaches	→	Conservative approaches
They don't know SFT	→	Ignorance of SFT
They have no experience with SFT		
They have no information about the benefits		
High purchase price	→	Financial demands
They do not pay to invest, they are small	→	Another source of information
They have information from the wine association		

Source: Author

Table 4. Categories of STF barriers by winemakers.

"We do not use any weather stations. We only have automatic shears for cutting the vineyard."

"We don't have a weather station, but we considered a combine with telematics, but the price discouraged us. But maybe we will try to look at a subsidy if something could not be used."

"We do not use our online weather station. If we need to know something about, for example, the amount of precipitation, temperatures and the like, then we will find out the information from a farmer's neighbor who uses the weather station. Unfortunately, I don't even know anyone who should have a weather station and actively use the data. Only someone who has hundreds of hectares of vineyards and agronomists does it."

"We do not use SFT because it is not worth investing in them. We make wine either for fun or just as extra income."

"This year, I take over the winery from my grandfather, which is why we are currently behind the times with smart technologies."

"We don't use any technologies of this type, we take care of everything ourselves, although it is more laborious and demanding, but it is still sufficient for our production."

"Many of our well-known winemakers are members of the Ekovín association, just like us. Every week, Ekovín sends a monitoring report with the current meteorological situation and forecast for the coming days, then some possible development of pests and other information."

STF providers and HW supplier perceive as the main barriers to using sensors and weather stations the following ones: conservative approaches; age of winemakers; ignorance of SFT; financial demands and low state support. The final coding structure is shown in Table 5.

First-order categories		*Aggregate themes*
Conservatism in agriculture	→	Conservative approaches
Traditional approaches		
Older winemakers who are afraid of change	→	Age of winemakers
Older winemakers who do not want to change anything		
Low awareness of winemakers about SFT	→	Ignorance of SFT
Ignorance of SFT		
Lack of finances	→	Financial demands
Low state support	→	Low state support

Source: Author

Table 5. Categories of STF barriers by STF providers and HW supplier.

"They've been doing it for 100 years, so they won't change it anymore."

"They often say - I'd rather just go there..."

"Farmers are very conservative and do not want

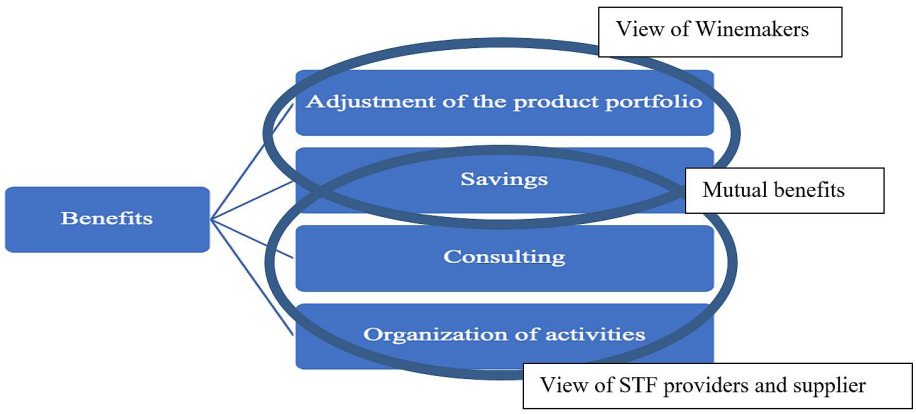
much change, especially those older winemakers. But the younger ones are already starting to ask and use SFT. When they get acquainted with SFT, they are excited and want to use them."

Theoretical implications

The present pilot study investigated how SFT, specifically sensors and weather stations, are used by small and medium winemakers. The results showed that winemakers are starting to use SFT and see the benefits in them. With regards to the Food & Beverage sector, particularly if the wine industry is taken into account, many scholars pointed out the dynamism and complexity of global markets (Mariani et al., 2012). Globalisation has boosted competition in wine markets (Giuliani et al., 2011) and firms are engaged to face the effects of globalisation and opportunities in new markets such as Chile, South Africa, Australia and China (Spadoni et al., 2019). It is SFT that can help winemakers succeed in this increasingly competitive market, thanks mainly to the financial savings that SFT offers. The study added a novel contribution to previous knowledge on typical SFT benefits and SFT barriers by small and medium winemakers, STF providers and HW supplier. The main STF benefits in viticulture perceived by the respondents are shown in Figure 1 and main SFT barriers are shown in Figure 2.

The main STF benefits perceived by the respondents are adjustment of the product portfolio, savings (of time, people and money), consulting and organization of activities. There are savings as mutual STF benefits in Figure 1. The advantages of savings, such as saving in time, human resources and money, in gasoline, fertilization, irrigation, and spraying were established by the pilot study. Caffaro and Cavallo (2019) noted that SFTs contribute to the provision of vast ecological benefits such as natural resources being adopted in a more efficient manner of a decrease in nutrient and pesticide usage. The study concurred with these findings. PA or PV translates into the specific areas of each field being assessed as a singular not collective entity and the levels of fertilizer, phytochemicals and/or water application being appropriately altered as a result. (Srinivasan, 2006). When used effectively, this targeted site management can improve the efficiency of agricultural inputs and lead to reduced costs and enhanced benefits. (Yost et al., 2017).

On the other hand, the main STF barriers mentioned by the respondents are low need for information, another source of information, conservative approaches, ignorance of SFT, financial demands, low state support and age of winemakers. There are conservative approaches, ignorance of SFT and financial demands as mutual STF barriers in Figure 2. Pejorative costs are the most common barriers to SFT adoption (Rogers 2003), a consistent trend many papers have noted (e.g., Paustian and Theuvsen 2017; Long et al. 2016). The price of sensors and weather stations are, however, falling, meaning a more important barrier is an adherence to traditional winemaking approaches and a lack of knowledge of SFT (see Table 4, Table 5 and Figure 2). Past papers on this topic noted a low uptake of SFT use, quite frequently accompanied by ostensibly illogical and wasteful actions on the part of farmers (Caffaro and Cavallo, 2019). Some users, for instance, adopted SFTs with success and tangible benefits, but still returned to more conventional forms of farming (e.g., Sneddon et al., 2011; Cullen et al., 2013).



Source: Author

Figure 1. SFT benefits for winemakers, STF providers and HW suppliers.

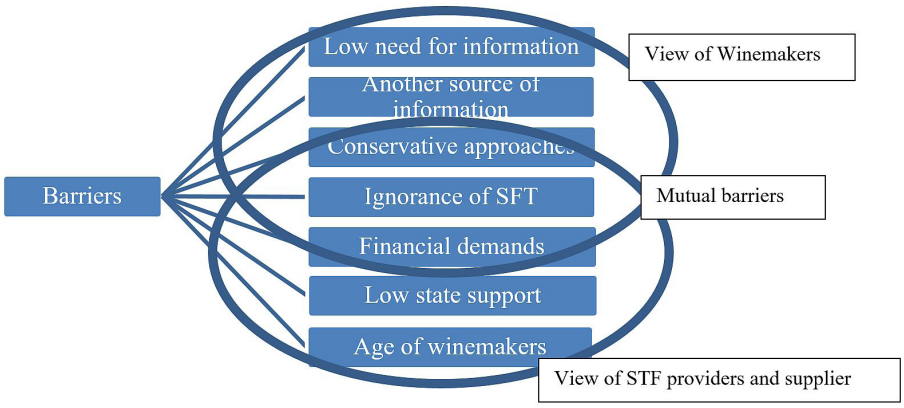
Previous research (e.g., Kernecker et al., 2020, Maffioli et al., 2013) have shown that a lack of information on existing innovative technologies as well as individual and impartial advisory services for farmers is a barrier to the widespread uptake of SFT across Europe, as confirmed by the pilot study. In particular, farmers called for independent private advice (Kernecker et al., 2020). Thus, targeted policies and support are recommended for better awareness of SFT (Knuth and Knierim, 2016). Farmers generally consider peer-to-peer communication to be an important source of information and regret the lack of impartial advice. This suggests that if the development and dissemination of the SFT needs to be improved, differences in agricultural structures and farming systems across Europe need to be considered (Kernecker et al., 2020). The low absorption of SFT was mentioned by Caffaro and Cavallo (2019), which is especially evident in older winemakers, respondents to the pilot study, who are used to their traditional practices and do not want to change anything about them. Further technological innovations may enable the smoother integration of reliable smart tools, product delineation and traditions within one agricultural system (Bernetti et al., 2006). Companies are currently wrestling with this balance between convention and technology, trying to keep a brand identity forged from long standing traditional values, while attempting to utilise SFT to get and stay ahead of their competitors (Vrontis et al., 2016).

While all farmers generally believe SFT to be useful for agriculture and broadly expect SFT to continue in terms of specific farm challenges, farmers are less convinced of the potential of SFT (Kernecker et al., 2020). Significantly, both adopting and non-adopting groups are hesitant about adopting SFTs, thus adopters are rather disappointed with the SFT they have experienced and non-adopting because they do not believe that appropriate technologies are available and easy to access (Kernecker et al., 2020).

Managerial implications

One of the advantages is certainly the selection of suitable biotypes or even new varieties for wine soil efficiently and with sufficient accuracy (Voutes et al., 2018), thanks to the information obtained from sensors and weather stations. However, it is necessary to acquire this data first and be able to process it and use it for further strategic steps. In order for such technologies to be more widely taken on there are challenges to be addressed in terms of not only further necessary exploration of these modern systems, but most predominantly about whether farm workers can be trained up into technicians with the ability to both comprehend and use them (Matese and Di Gennaro, 2015). Furthermore, the study investigated this issue in the Czech Republic, where the winemaking tradition is long, and many wineries have received good ratings. Many young winemakers are also starting to get ahead and try to differentiate themselves from traditional winemakers with their methods of cultivation, processing, distribution and promotion. As Dressler and Paunovic (2020) mention, wine regions in the "old world" countries like Germany need to innovate production practices in order to stay competitive in the world wine market.

Overall, consistent with previous studies performed in different countries (e.g., Kernecker et al., 2020; Caffaro and Cavallo, 2019), research results mapping the use of SFT by small and medium-sized wine growers have shown that interest in SFT among winegrowers is growing every



Source: Author

Figure 2. SFT barriers for winemakers, STF providers and HW suppliers.

year, thanks to the rejuvenation of winegrowers and the ever faster development and implementation of SFT into daily life. However, it is necessary to inform winemakers about these SFTs, including sensors and weather stations, their benefits and the use of the data obtained. Events for winemakers, wine association websites, wine conferences and exhibitions, articles in wine magazines and other wine-oriented activities are ideal. It is important to build a community of enthusiastic SFT adopters. However, personal recommendations are still very important. A good experience of a fellow winemaker who informs others about the benefits and what SFT specifically brought them is still the best advertisement even in today's digital age. This is even more important in traditional industries, where wineries still belong. A very similar situation to viticulture is beginning to be hop growers, where some SFT providers see research potential and are starting to direct their SFTs to them more and more.

Farmers will increasingly operate as managers and supervisors of machinery rather than actually working in the field. Given that the next farming generation are “sons of the internet”, they are predicted to naturally adopt SFT (experts from industry) (Kernecker et al., 2020). Knowledge in the field of information and communication technologies has become an essential condition for the success of managers in all areas of economic activity (Hallová et al., 2017). For winemakers, the opportunity is to streamline work processes using network machines. The processes that take place during the alcohol fermentation phase can be controlled and monitored (Průžek, 2019). It is possible to influence any end product in monitoring key indicators in production and using a standardized process, so in wine production it is possible to help by standardizing, digitizing documentation and using barcodes, QR codes or RFID technologies. This allows the process to be monitored at each stage of wine production and the resulting quality be influenced (Průžek, 2019).

Limitations of the paper

There are two main areas of limits in this paper. Firstly, due to the very small sample of winemakers from only one wine region, this research cannot represent the general population of winemakers. Therefore, this pilot study cannot account for the results, because it is not a representative selection, but the study maps this issue of the use of SFT in viticulture and shows SFT benefits and SFT barriers. Therefore, it would certainly be very interesting to address a larger number of winemakers and verify the information obtained from the first interviews and further deepen this issue. Secondly, the process of coding the information obtained from research to identify key categories and topics was performed primarily by the author of the article. Then there was a consultation of categories and topics with a colleague, but it is still nonetheless very subjective.

Conclusion

This Third Green Revolution is imposing itself across the agricultural world via the combined application of ICT solutions such as precision equipment, sensors and actuators, Big Data, the Internet of Things (IoT), geo-positioning systems, Unmanned Aerial Vehicles (UAVs, drones), robotics, etc. (Smart Akis, 2020). This paper contributes to better understanding the use of SFT in viticulture, especially by small and medium winemakers. SFT, which is the most recent wave of innovations, promises to improve farming by responding to economic, ecological, and social challenges and thereby sustainably develop agriculture throughout Europe (Kernecker et al., 2020).

According to the information of winemakers, it is clear that SFT are used by some of them. Winemakers are clearly aware of their benefits, which is also confirmed by SFT providers. The findings revealed that the main STF benefits are adjustment of the product portfolio, savings (of time, people and money), consulting and organization of activities. However, respondents also mentioned barriers to SFT implementation, such as low need for information, another source of information, conservative approaches, ignorance of SFT, financial demands, low state support and age of winemakers. There are savings as mutual STF benefits and conservative approaches, ignorance of SFT and financial demands as mutual STF barriers perceived by respondents. The findings will be confirmed by further investigations by more winemakers. Digitization therefore offers great potential for improvement in this area and can contribute to a better use of limited resources. For winemakers themselves, the use of SFT can bring many aforementioned benefits, but there is still a need to overcome barriers, especially in a truly conceived winery. The wine industry faces the same challenge of implementing efficient systems as other industries do.

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Predicting Trends in Cereal Production in the Czech Republic by Means of Neural Networks

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Abstract

This paper deals with problems of processing agricultural production data into the form of time series and analysing consequent results by means of two completely different methods. The first method for calculating cereals production figures uses the MS-Excel spreadsheet using conventional mathematical and statistical functions while the second one uses the ELKI software providing users with development environment including algorithms of neural networks. The obtained results are similar to a certain extent which shows new possibilities of progressive use of neural networks in future and enables modern approach to analysing time series not only in agricultural sector.

Keywords

Comparative analysis, cereals production, ELKI software, Excel spreadsheet, neural networks, predicting, statistics, time series, trends.

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Introduction

In the area of the Czech Republic, common cereals – wheat, rye, barley, and oats – always have dominated and represented amount of 50%–60% of the whole crop farming volume (Liu et al., 2005). In the course of their existence, the statistical records show significant fluctuating of yield values in the period of 1920–2018 and prove no definite trend (Kůst and Záruba, 2020). Also volume proportions of individual crops constantly have changed. In the beginning, rye as a source of flour for baking of bread was the most grown plant but it was gradually replaced by wheat similarly as in the case of oats previously bountifully used as feedstuff for farm animals (Némethová et al., 2004). The area of fields for production of barley largely used in the beer industry decreased too while the area for wheat production increased for 240% of pre-war level (Hruška 2019). Development of maize production in the Czech Republic is interesting – since the fifties, area for production of maize used predominantly for ensilaging began to extend together with applying of artificial fertilizers while by the end of the eighties a significant decrease came. However, arrival of the new millennium brought considerable boom in maize growing because this crop became a strategic item as a fuel for biogas power stations producing renewable energy (Hruška, 2014).

Also the total area of agricultural land has changed in the course of time. Post-war area decrease due to topsoil occupation for extending cities and industrial complexes continued not until the end of the eighties (Šťastný, 2011). On the other hand, intensity of agricultural production increased. After 1989, the decrease accelerated and, just before the Czech accession to the EU in 2004, the total area of the agricultural land decreased to 2.6 million hectares (Hruška, 2014). However, not due to occupation for construction industry but for reasons of massive extensive swarding namely in submontane and montane regions.

This paper provides descriptions of two very different methodologies for forecasting of cereals production trends (for both entities – total and individual crops): forecasting by means of spreadsheet (Excel) using conventional mathematical and statistical functions and the ELKI software using neural networks

algorithms (Phillips and Hansen, 2001). Both methods work with the identical input data adopted from the Czech Statistic Office data (Czech Statistic Office, 2019). All results are shown in transparent diagrams and accompanied by comparative analysis explaining differences between the results of both methods (Brožová and Beranová, 2017).

Materials and methods

Forecasting by means of Excel spreadsheet

For predicting future development of time series, the MS-Excel spreadsheet ranks among the best commonly available software tools (Köppelová and Jindrová, 2017). For such the calculating, the spreadsheet use the method of exponential smoothing (Kačer, 2013). At this method, time series are being replaced by different mathematic curves and, concurrently, the weights of individual records are exponentially decreased pastwards. In fact, it works as low-pass filtering when high-frequency noise is eliminated.

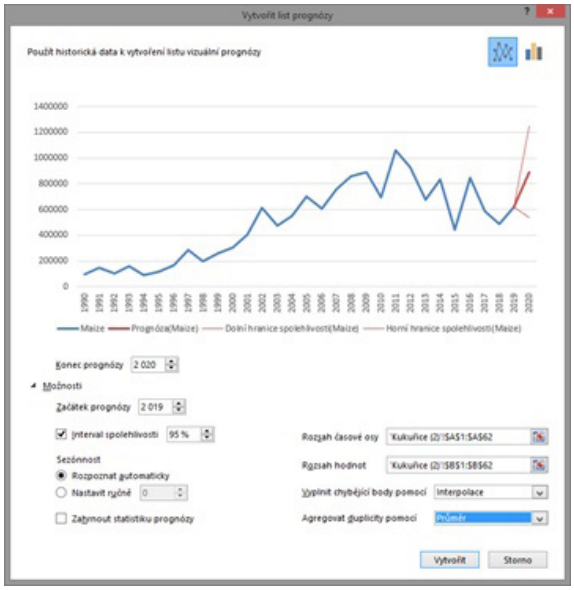

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Figure 1: Setup in Excel Create Forecast Worksheet dialogue box.

The guide to the *Create Forecast Worksheet (List prognózy)* provides analysts with possibility to set prognosing process parameters and, then, the function creates a new sheet containing both historical and predicated values including a diagram (see Figure 1). For prognoses of trends in cereal production in the Czech Republic, the following parameters were setup – *Forecast End (Konec prognózy)*: 2050; *Forecast Start (Začátek prognózy)*: 2020; *Confidence interval (Interval spolehlivosti)*: 95%; *Seasonality Detect (Sezónnost):* Detect Automatically (Rozpoznat automaticky); *Include Forecasts Statistics (Zahrnout statistiku prognózy)*: No; *Timeline Range & Values Range (Rozsah časové osy a Rozsah hodnot)*: automatically detected by Excel; *Fill Missing Points Using (Vyplnit chybějící body pomocí)*: Interpolation (Interpolace); *Aggregate Duplicates Using (Agregovat duplicita pomocí)*: Average (Průměr). The FORECAST.ETS function calculates values based on entered arguments (forecast start, historical data, timeline, seasonality, forecast end, aggregation) using exponential smoothing while the FORECAST.ETS.CONFIT function calculates the confidence interval showing how many percent for future points come under into the future result range (the narrower intervals the more accurate results) (Melart, 2016).

Forecasting by means ELKI software – Neural networks

The Java-based ELKI software represents a free software machine learning library for the Java programming language. ELKI represents a modular system with the object-oriented architecture integrating different components for machine learning and data mining by means its excellent modular data flow processing design. ELKI provides a competitive method against traditional methods by means of special algorithms representing neural networks as, for example, arbitrary algorithms, data types, distance functions, indexes, and evaluation measures. The application uses self-learning using sample data that may contain unknown or hardly expressible inner contexts that can be loaded by noise. Ability of noise filtering and finding of natural development relations belong to its most significant properties for processing of prognostic problems (Allen, 1994). Multi-level artificial neuron networks represent universal approximating (both linear and non-linear) tool usable for creating an *n*-variables function model in the course of learning process based on sample data. For purposes of prognoses creating, it is possible to create differently difficult models, however, solving several basic problems (neuron network configuring, calculating function of neurons, precision of neuron network learning, etc.) is essential for successful use of the neuron network (Singireddy, 2010). In cases of simpler tasks, there is not need any mathematic prediction model – providing a neural network with a data set used to be enough, the network is able to choice its own model (mostly very appropriate one). The numbers of inputs and outputs are given by a type of neural networks and represent two basic configuration parameters (Kačer, 2013).

However, creating of some approximation model of a multivariable function is essential for using a multi-level neural network. Network configuration (i.e. number of both input and output neurons, total number of neurons, number of neurons in hidden layer, number of hidden layers, and calculating function) affect the model properties. On Figure 2, there is a scheme of *n*-layer network modelling O_i $(x_1, x_2, \ldots, x_p)$ functions.

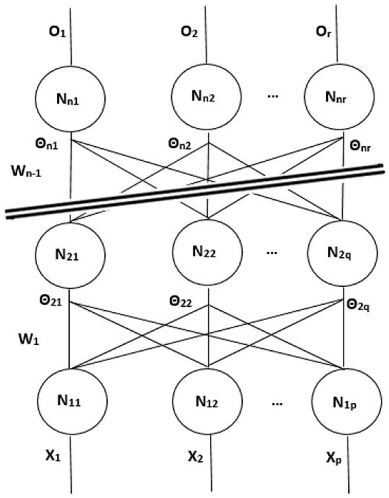

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Figure 2: Scheme of *n*-layer network modelling O_i functions.

If the neural network consists of *p* input neurons, *q* neurons in hidden layers, and *r* output neurons then, for learning process, the following parameters must be set:

- $q\ (p + 1)$ parameters between the input and first hidden layer;
- $(n - 3)\ (q + 1)\ q$ parameters in hidden layers $(n \geq 3)$;
- $(q + 1)\ r$ parameters in output layer.

In total, it means

$$S_n = q\ (p + 1) + (q + 1)\ [q\ (n - 3) + r] \qquad (1)$$

of parameters represented by weights W_i and threshold values Θ_i. The numerous neurons within hidden layers the higher number of parameters and, concurrently, better possibilities of modelling of more complex functions. However, only hidden layer with $q \geq \min(p, r)$ or $q = \max(p, r)$ neurons is enough for most of tasks. In the case of equality in the expression $q \geq \min(p, r)$, minimizing of number of neurons in hidden layers is ensured, however, network learning may be worse (more learning sessions may be required). For the reason, the expression $q = \max(p, r)$ should be used in the beginning and, subsequently, a number of neurons or even layers may be decreased or increased. A function of neurons also affects the model properties (Kačer, 2013). For the purpose, the activation functions

$$Y_1(x) = \frac{1}{1+e^{-x}}, \text{ where } Y_1(x) \in (0, 1) \qquad (2)$$

or

$$Y_2(x) = \frac{Y_{max} - Y_{min}}{1+e^{-x}}, \text{ where } Y_2(x) \in (Y_{min}, Y_{max}) \qquad (3)$$

or

$$Y_3(x) = k \cdot x, \text{ where } k < 1 \text{ (for example } k \approx 0.1) \qquad (4)$$

are used.

To minimize a value of the error function, the method of backward error spreading is processed through learning of the multi-level neural network based on samples (learning with teacher) (Köppelová and Jindrová, 2019).

$$E = \frac{1}{2}\sum_i \sum_j [\, Y_j(X_i) - Y_j^{\circ}(X_i)]^2 \qquad (5)$$

where $Y_j^{\circ}(X_i)$ is a required value while $Y_j\ (X_i)$ is a real value of the j-th output at inputs given by the X_i vector. The learning process is completed when the value of error function $E < E_0$ (entered value) is achieved when the absolute value of change of the error function for a given number of learning phases is lower than the entered value, i.e. $\frac{|\Delta E|}{N_e} \leq \delta$ (N_e – entered value) or after completing of requested number of repeating (Kačer, 2013).

A basic trend model is derived from general perspective on behaviour of a system with memory whose outputs are in a given time instance dependent on current inputs and inner states of the system (Rakhmatulin, 2020).

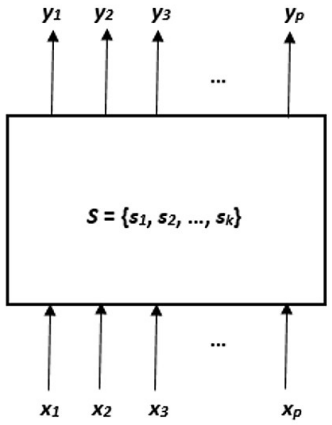

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Figure 3: Scheme of common system.

If $X = \{x_1, x_2, x_3, \ldots, x_p\}$ is the input vector

(see Figure 3) and $S = \{s_1, s_2, s_3, ..., s_p\}$ is the vector of system inner states then the system outputs $Y = \{y_1, y_2, y_3, ..., y_p\}$ can be considered as dependencies $y_i(t) = f_i\ [X(t-1), S(t-1)]$ or $Y(t) = F\ [X(t-1), S(t-1)]$.

Generally, time series of multiple outputs or even input parameters (in the form of time series again) can be available for researching of future system behaviour (Šnorek and Jiřina, 1996). State values and, in most of cases, also system inputs are unknown and, that is why, they are almost undetectable and, therefore, it is not possible to create any prognostic model in any direct way (Köppelová and Svatošová, 2019). In the case of unavailable values of system states and inputs, it is necessary to express the assumption that an appropriate information is included in the output values because each value of output time series is dependent on the system states and inputs (Kačer, 2013). The model function for prediction of future values of time series Y can be formally expressed as:

$$Y(t) = \mathrm{F}\ [Y(t-1), Y(t-2), \dots, Y(t-k)], \qquad (6)$$

where k represents a number of values of the time series used for prediction of a requested value. The expression (6) is a formal representation of the function of the prediction model with the neural network (see Figure 4). A default structure of the neural network for this prognostic model contains

$$N_{in} = r \cdot k \qquad (7)$$

neurons in the input layer, r neurons in the output layer, and $r \cdot k$ neurons in the hidden layer. In the case, not only time series of output values but also input values are available, then it is possible to create the model enabling to research influence of X inputs on Y outputs of the system. The formal function of such the model can be expressed as:

$$Y(t) = F\ [Y(\mathrm{t}-1), Y(t-2), \dots, Y(t-k), X(t), X(t-1), X(\mathrm{t}-2), \dots, X(t-k)]. \qquad (8)$$

Formally, this expression represents a prognostic model shown on the Figures 2, 3 and 4. In this case, the neural network includes

$$N_{in} = (p + r)k + p \qquad (9)$$

input neurons; the same number of neurons is contained also in the hidden layer. The expressions (6) and (8) are representatives of structures of learning files of the appropriate models. After learning process, the neural network is used in calculating mode in which one value of Y(t) outputs is calculated based on the last k values of time series X and Y and p input values $X(t)$. By completing of the calculated values into the appropriate time series, it is possible to carry out any number of prediction steps and, so, to obtain a development prognosis of an appropriate quantity for longer time period (Kung et al., 2018).

The configuration of multi-layer neural networks consist in determining of network inputs and outputs, hidden layers, and neurons in them. The higher amount of parameter the more complex network and, concurrently, possibility of more precise modelling of the requested function defined by a remainder of time series. However, too high value of the parameter need not increase model quality and, vice versa, too lower value may cause excessive filtration – that is why some optimum value at which the model function is the best should

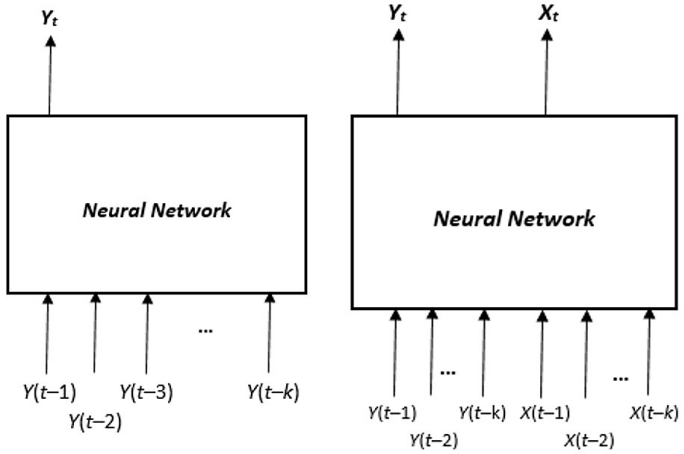

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Figure 4: Basic trend models.

be chosen (Kačer, 2013). Mostly, the models based on multi-layer neuron networks with only hidden layer used to be enough. In the case of neuron linear function, a network with only input and output layer is enough because more complex networks can be transformed to the function of such the simple neuron network.

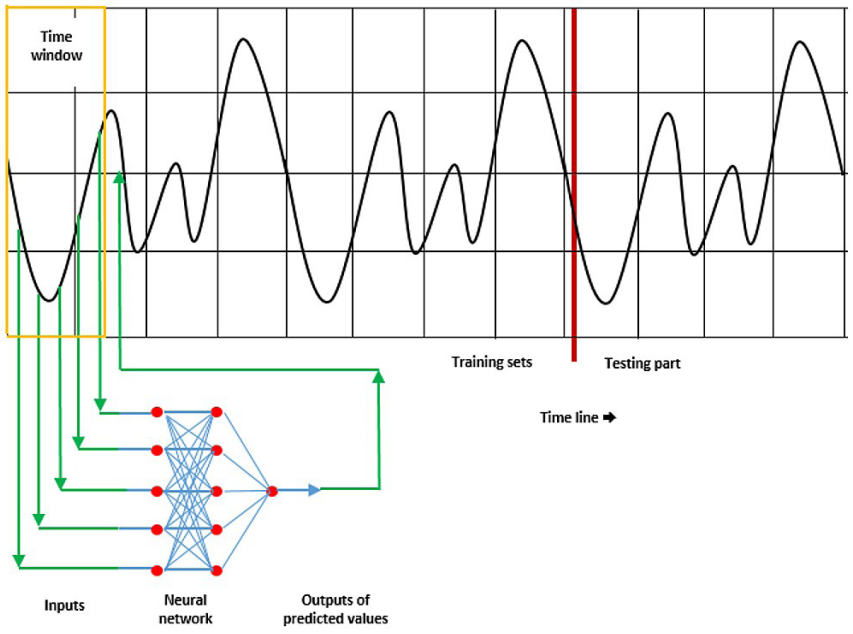
In the phase of learning of the neural network (with determined numbers of neurons in layers and their relations and transformation function) with a teacher, the values of weights and thresholds are progressively set up. After processing of input data, the outputs are compared with the requested outputs and, after that, some corrections (i.e. changes of weights and thresholds) should be carried out to achieve the smallest possible difference between the real and requested outputs. The system represented by time series has a certain "inertia" i.e. the value $Y_n = Y(t)$ does not notably differ from $Y_{n-1} = Y(t\text{-}1)$. Then, it is necessary to find such the value of error function E of neural network learning at which the prediction error E_p is minimal:

$$E_p = \frac{1}{2}(Y_n^p - Y_n)^2, \quad (6)$$

where Y_n is the last value of the explored time series and Y_n^p is the value predicted by the model. By minimizing of the function $E_p(E)$, the optimum value (with minimum E_p) of neuron network learning is found (Yao et al., 2017). If no satisfactory result is achieved, then it is possible to change the value of parameter k, neuronal function, or even a number of network layers.

A testing set is created directly from time series so that inputs are represented by a certain number of recorded values and requested outputs by values in the specific distance from the input values. The input part represents a time window while the output part is a predicted value. Offsetting the time window along the time line creates items of the training set (see Figure 5). A part of the recorded set ought to be let for testing purposes which means this part of the time series should not be used during learning phase but during of testing of actual learning status (Obitko, 2019). Further, the completed training set has to be adjusted for use with a particular neural network (recalculating obtained values into the certain interval, etc.).

The disposable data are often classified to a learning set, validating set, and testing set. These three sets can be overlaid (see Figure 5) and need not be coherent. The learning set is a progression introduce to the network serving for its follow-up adjusting (Niedbała, 2019). The deviations contained in answers is used as a criterion for completing of the learning process. Afterwards, the testing set is used for testing of actual "knowledge" status applied for predicting future (formerly "unseen") values. So, the learning set serves for model searching, the validation set for model validating, and the testing set for testing of the applicability (Figure 6).



Source: Obitko (1999).

Figure 5: Creating training sets.

Data pre-processing represents an important part of the whole process. For example, removing trends or seasonal component (of course if identifiable) is of particular appropriateness. The neural networks with outputs falling within the fixed boundaries show only poor serviceability in predicting of values falling out of the intervals specified in advance. Then, the correctly configured neural network is able to solve various tasks.

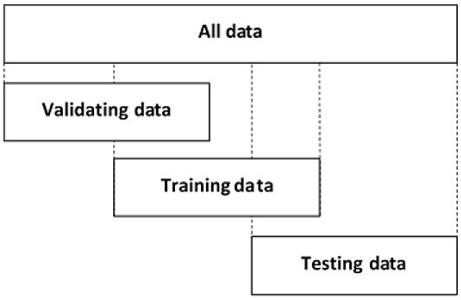


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Figure 6: Scheme of arrangement of data sets.

Data pre-processing represents an important part of the whole process. For example, removing trends or seasonal component (of course if identifiable) is of particular appropriateness. The neural networks with outputs falling within the fixed boundaries show only poor serviceability in predicting of values falling out of the intervals specified in advance. Then, the correctly configured neural network is able to solve various tasks.

Results and discussion

Resulting diagrams (Figures 7-12) include three data categories originating from preceding table pairs: historical data (Tables 1-6) based on data of the Czech Statistic Office (*Year, Production*), predicted data (*Prognosis, Lower Endpoint, Upper Endpoint*) calculated by means of Excel´s *Create Forecast Worksheet* procedure, and data predicted by help of ELKI neural networks (*Neural Network*).

While the data originating from the Czech Statistic Office provided the spreadsheet with inputs for calculating the first type of prognosis including lower and upper endpoints (table columns and diagram curves named *Prognosis, Lower Endpoint, Upper Endpoint*), the columns of values calculated within the environment of the ELKI neural network software (named *Neural Network*) were copied into the sheet additionally so that they can be processed into the integrated diagrams.

In all cases, the results generated by means of the neural network are more or less similar to prognoses values calculated by the spreadsheet. Neither lower nor upper endpoints variants were processed by the neural networks because only trend prognoses represented the purpose of the comparative analysis.

Cereals (total)

The production prognosis of all main kinds of cereals (wheat, rye, barley, oats, and maize) show only a very moderate increase (Köppelová and Jindrová, 2019). The neural networks prognosis fluctuates a bit form the main prognosis generated by means of the exponential smoothing method (Table 1, 2; Figure 7).

Wheat

The wheat production prognosis moderately rises while neural network prognosis shows relatively lesser deviations than in the case of total cereals production (Table 3, 4; Figure 8).

Rye

The rye production prognosis rapidly decreases, lower endpoint soon achieves zero level followed by main prediction generated by spreadsheet and neural networks. In fact, the zero values represented negative values and, for the purpose of rational interpreting the data they were transformed to zero level (Table 5, 6; Figure 9).

Year	Production (t)	Year	Production (t)	Year	Production (t)
1990	8946879	2000	6454237	2010	6877619
1991	7845290	2001	7337589	2011	8284806
1992	6564898	2002	6770829	2012	6595493
1993	6467852	2003	5762396	2013	7512612
1994	6777231	2004	8783801	2014	8779299
1995	6601711	2005	7659851	2015	8183512
1996	6644145	2006	6386078	2016	8596408
1997	6982772	2007	7152861	2017	7456779
1998	6668920	2008	8369503	2018	6970919
1999	6928371	2009	7831998	2019	7646148

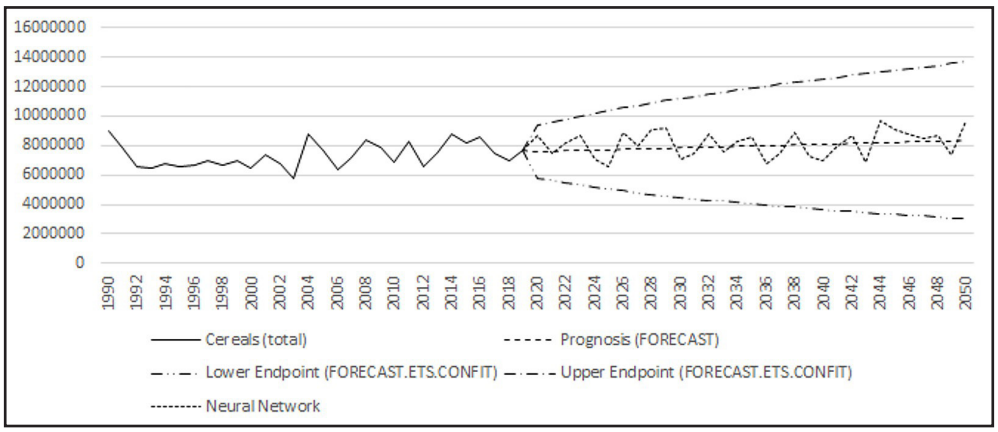
Source: CSO

Table 1: Total cereals production in period of 1990–2020.

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2020	7646148	7646148	7646148	7646148
2021	7619229	5632248	9606211	7472624
2022	7644466	5466529	9822402	8189064
2023	7669702	5315580	10023824	8636399
2024	7694938	5176297	10213579	7104460
2025	7720175	5046525	10393824	6597024
2026	7745411	4924695	10566126	8885206
2027	7770647	4809622	10731672	8024484
2028	7795883	4700386	10891381	9062427
2029	7821120	4596255	11045984	9164711
2030	7846356	4496637	11196075	7111268
2031	7871592	4401045	11342140	7491012
2032	7896828	4309070	11484587	8748790
2033	7922065	4220368	11623762	7625641
2034	7947301	4134644	11759958	8247687
2035	7972537	4051646	11893428	8531530
2036	7997773	3971152	12024395	6766181
2037	8023010	3892970	12153049	7510691
2038	8048246	3816929	12279563	8846229
2039	8073482	3742878	12404087	7278906
2040	8098718	3670682	12526755	6953007
2041	8123955	3600222	12647688	7965763
2042	8149191	3531388	12766994	8706416
2043	8174427	3464083	12884772	6849893
2044	8199664	3398216	13001111	9672900
2045	8224900	3333708	13116091	9096176
2046	8250136	3270485	13229788	8782732
2047	8275372	3208477	13342268	8463229
2048	8300609	3147623	13453594	8674356
2049	8325845	3087866	13563824	7413610
2050	8351081	3029152	13673010	9726782

Source: CSO and author´s procession

Table 2: Prognoses of total cereals production in period of 2020–2050 by means of ETS algorithm and neural network.



Source: CSO and author´s procession

Figure 7: Prognoses of total cereals production by means of ETS algorithm and neural network.

Year	Production (t)	Year	Production (t)	Year	Production (t)
1990	4624190	2000	4084107	2010	4161553
1991	4081279	2001	4476080	2011	4913048
1992	3412943	2002	3866473	2012	3518896
1993	3304271	2003	2637891	2013	4700696
1994	3713476	2004	5042523	2014	5442349
1995	3822769	2005	4145039	2015	5274272
1996	3727203	2006	3506252	2016	5454663
1997	3640269	2007	3938924	2017	4718205
1998	3844741	2008	4631502	2018	4417841
1999	4028271	2009	4358073	2019	4812163

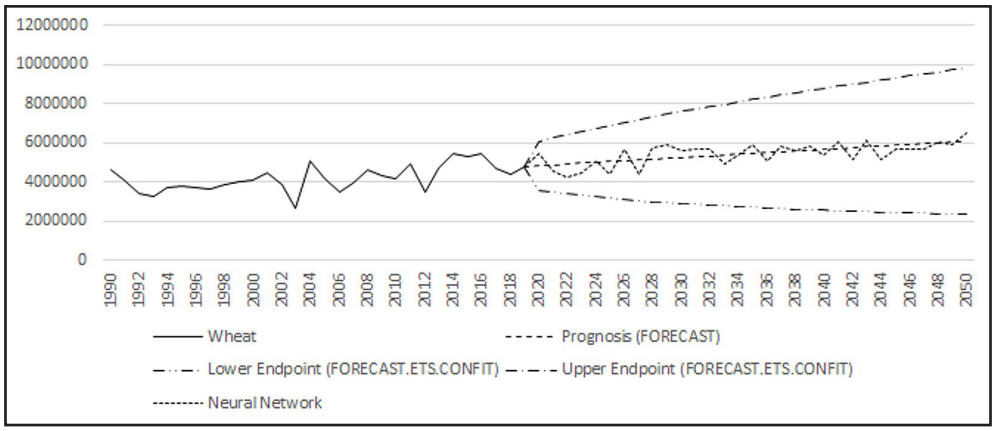
Source: CSO

Table 3: Wheat production in period of 1990–2020 .

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2020	4842851	3597441	6088260	5420868
2021	4884370	3491402	6277337	4561171
2022	4925889	3399053	6452725	4261918
2023	4967407	3317057	6617758	4493976
2024	5008926	3243241	6774612	5114009
2025	5050445	3176092	6924799	4369862
2026	5091964	3114510	7069418	5689983
2027	5133483	3057665	7209301	4395625
2028	5175002	3004912	7345091	5754819
2029	5216521	2955739	7477303	5872656
2030	5258040	2909729	7606350	5621003
2031	5299559	2866542	7732576	5689307
2032	5341078	2825890	7856265	5672014
2033	5382596	2787533	7977660	4944172
2034	5424115	2751264	8096967	5417156
2035	5465634	2716905	8214363	5899624
2036	5507153	2684302	8330004	5048731
2037	5548672	2653320	8444024	5861215
2038	5590191	2623839	8556543	5581260
2039	5631710	2595752	8667667	5836822
2040	5673229	2568967	8777490	5370144
2041	5714748	2543398	8886097	6066215
2042	5756267	2518970	8993564	5171722
2043	5797785	2495612	9099959	6158083
2044	5839304	2473264	9205345	5147530
2045	5880823	2451868	9309778	5711101
2046	5922342	2431372	9413312	5716505
2047	5963861	2411729	9515993	5711375
2048	6005380	2392895	9617865	6075366
2049	6046899	2374830	9718968	5929710
2050	6088418	2357495	9819340	6532677

Source: CSO and author´s procession

Table 4: Prognoses of wheat production in period of 2020–2050 by means of ETS algorithm and neural network



Source: CSO and author´s procession

Figure 8: Prognoses of wheat production by means of ETS algorithm and neural.

Year	Production (t)	Year	Production (t)	Year	Production (t)
1990	557712	2000	150052	2010	118233
1991	352992	2001	149298	2011	118456
1992	240067	2002	119154	2012	146962
1993	256079	2003	159312	2013	176278
1994	275654	2004	313348	2014	129059
1995	261938	2005	196755	2015	107874
1996	204279	2006	74811	2016	104353
1997	259412	2007	177507	2017	109241
1998	261167	2008	209787	2018	120160
1999	202373	2009	178070	2019	157561

Source: CSO

Table 5: Rye production in period of 1990–2020.

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2020	144828	9438	280218	56499
2021	136842	0	319081	243279
2022	128855	0	348230	56657
2023	120869	0	372010	213594
2024	112882	0	392260	155000
2025	104896	0	409962	188309
2026	96910	0	425713	47492
2027	88923	0	439909	166332
2028	80937	0	452829	4105
2029	72950	0	464677	104978
2030	64964	0	475609	114772
2031	56978	0	485746	167245
2032	48991	0	495185	148549
2033	41005	0	504004	124401
2034	33018	0	512270	3138
2035	25032	0	520036	0

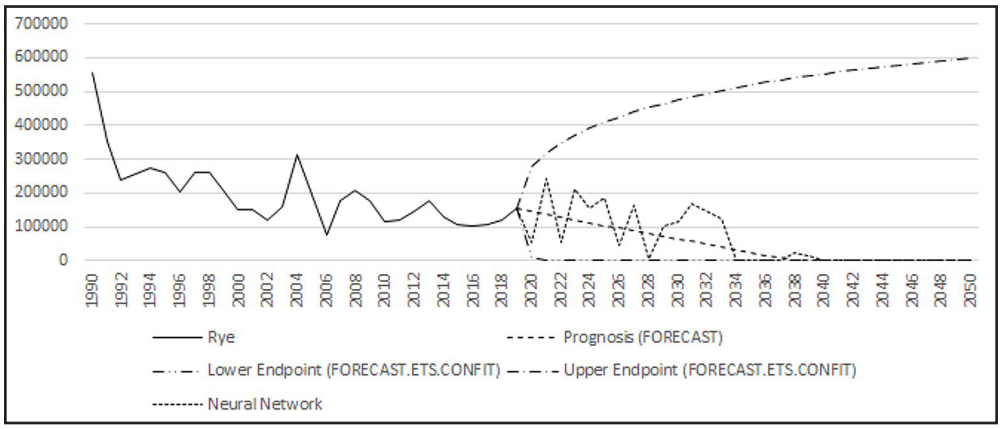
Source: CSO and author´s procession

Table 6: Prognoses of rye production in period of 2020–2050 by means of ETS algorithm and neural network (to be continued).

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2036	17046	0	527348	0
2037	9059	0	534248	0
2038	1073	0	540767	24538
2039	0	0	546938	14954
2040	0	0	552785	0
2041	0	0	558332	3928
2042	0	0	563600	0
2043	0	0	568606	0
2044	0	0	573367	0
2045	0	0	577899	0
2046	0	0	582213	0
2047	0	0	586324	0
2048	0	0	590241	0
2049	0	0	593975	0
2050	0	0	597535	0

Source: CSO and author´s procession

Table 6: Prognoses of rye production in period of 2020–2050 by means of ETS algorithm and neural network (continuation).



Source: CSO and author´s procession

Figure 9: Prognoses of rye production by means of ETS algorithm and neural.

Barley

The barley production prognosis is very similar to rye one. Deviations of the curve generated by the neural network are more significant and, the values in the period 2034–2037 achieved negative values but, during 2038–2040, moderately rise to the positive ones again. It should be noted that it is only a demonstrative estimation and the real trend development may probably very differ (Table 7, 8; Figure 10).

Oats

Also the oats production prognosis show substantial decrease. Strong fluctuating the prognosis curve generated by the neural networks along the zero line is worth noticing. The predicted development is very similar to prognoses for rye and barley (Table 9, 10; Figure 11).

Maize

The maize production prognosis shows the fastest increase among another cereals. The markedly narrow area formed by the upper lower endpoints boundaries is caused by relatively more moderate fluctuating of values within the historical data. No values achieve the zero (negative) level (Table 11, 12; Figure 12).

Year	Production (t)	Year	Production (t)	Year	Production (t)
1990	3157299	2000	1629372	2010	1584456
1991	2833023	2001	1965611	2011	1813679
1992	2512490	2002	1792557	2012	1616467
1993	2418517	2003	2068693	2013	1593760
1994	2419297	2004	2330582	2014	1967049
1995	2140487	2005	2195376	2015	1991415
1996	2262377	2006	1897703	2016	1845254
1997	2484548	2007	1893408	2017	1712279
1998	2093101	2008	2243865	2018	1606034
1999	2137376	2009	2003032	2019	1718061

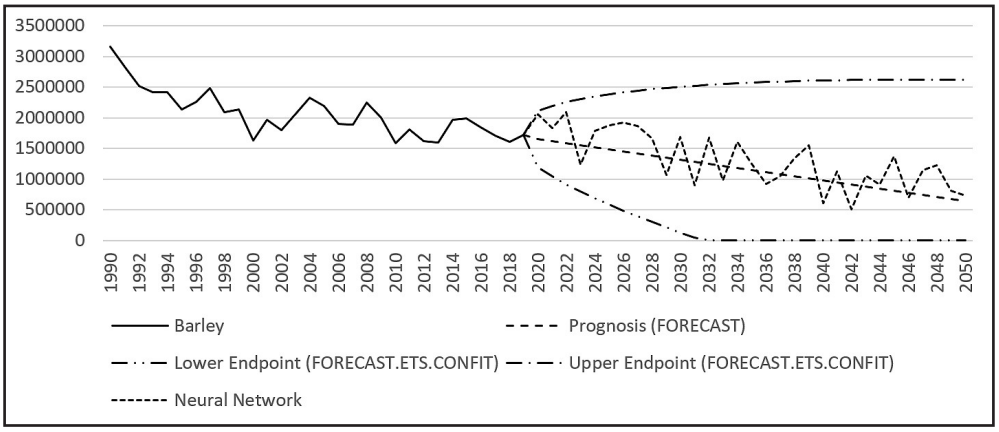
Source: CSO

Table 7: Barley production in period of 1990–2020.

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2020	1718061	1718061	1718061	1718061
2021	1654066	1194395	2113736	2059985
2022	1620213	1045349	2195077	1832993
2023	1586360	915571	2257149	2096418
2024	1552507	797679	2307334	1241298
2025	1518654	688057	2349250	1783129
2026	1484801	584615	2384987	1874070
2027	1450948	486013	2415882	1916401
2028	1417095	391336	2442854	1860193
2029	1383242	299920	2466563	1667709
2030	1349389	211272	2487506	1068591
2031	1315536	125009	2506063	1686187
2032	1281683	40828	2522538	901426
2033	1247830	0	2537175	1672136
2034	1213977	0	2550173	975554
2035	1180124	0	2561700	1604940
2036	1146271	0	2571897	1249923
2037	1112418	0	2580883	920515
2038	1078565	0	2588761	1043732
2039	1044712	0	2595622	1339926
2040	1010859	0	2601542	1552994
2041	977006	0	2606592	605118
2042	943153	0	2610832	1125660
2043	909300	0	2614317	503165
2044	875447	0	2617096	1053293
2045	841594	0	2619211	905003
2046	807741	0	2620704	1374970
2047	773888	0	2621609	701877
2048	740035	0	2621959	1150383
2049	706182	0	2621784	1228320
2050	672329	0	2621112	812955

Source: CSO and author´s procession

Table 8: Prognoses of barley production in period of 2020–2050 by means of ETS algorithm and neural network.



Source: CSO and author´s procession

Figure 10: Prognoses of barley production by means of ETS algorithm and neural.

Year	Production (t)	Year	Production (t)	Year	Production (t)
1990	373951	2000	135858	2010	138224
1991	301682	2001	136363	2011	164248
1992	207918	2002	167708	2012	171976
1993	262594	2003	233560	2013	139120
1994	207562	2004	227017	2014	152232
1995	186693	2005	151054	2015	154576
1996	214163	2006	154906	2016	132220
1997	246637	2007	159408	2017	142441
1998	179671	2008	155868	2018	152656
1999	179130	2009	165993	2019	134410

Source: CSO

Table 9: Oats production in period of 1990–2020.

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2020	130964	57845	204084	137016
2021	126319	27899	224740	183063
2022	121674	3198	240150	110438
2023	117029	0	252661	133952
2024	112384	0	263265	92507
2025	107739	0	272493	118497
2026	103094	0	280668	138850
2027	98449	0	288003	132575
2028	93804	0	294649	49956
2029	89159	0	300716	53343
2030	84513	0	306288	78769
2031	79868	0	311430	128041
2032	75223	0	316196	41318
2033	70578	0	320627	42248
2034	65933	0	324759	0
2035	61288	0	328621	0
2036	56643	0	332238	42730

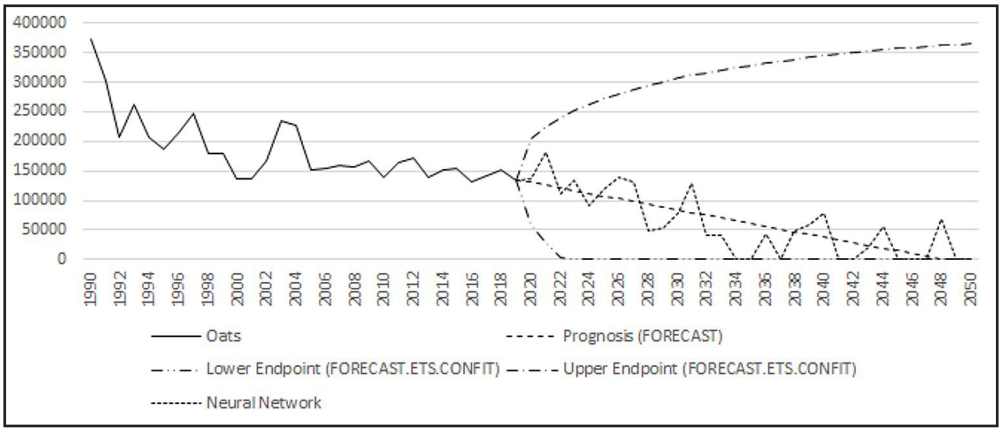
Source: CSO and author´s procession

Table 10: Prognoses of oats production in period of 2020–2050 by means of ETS algorithm and neural network (to be continued)..

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2037	51998	0	335632	0
2038	47353	0	338822	47501
2039	42708	0	341822	58217
2040	38063	0	344648	78054
2041	33418	0	347312	0
2042	28772	0	349825	0
2043	24127	0	352196	21724
2044	19482	0	354436	56082
2045	14837	0	356551	0
2046	10192	0	358550	0
2047	5547	0	360438	0
2048	902	0	362221	68870
2049	0	0	363906	0
2050	0	0	365496	0

Source: CSO and author´s procession

Table 10: Prognoses of oats production in period of 2020–2050 by means of ETS algorithm and neural network (continuation).



Source: CSO and author´s procession

Figure 11: Prognoses of oats production by means of ETS algorithm and neural.

Year	Production (t)	Year	Production (t)	Year	Production (t)
1990	98 381	2000	303 957	2010	692 589
1991	150 280	2001	408 653	2011	1 063 736
1992	103 720	2002	616 234	2012	928 147
1993	157 045	2003	476 371	2013	675 380
1994	91 396	2004	551 628	2014	832 235
1995	113 274	2005	702 933	2015	442 709
1996	168 684	2006	606 366	2016	845 765
1997	285 199	2007	758 781	2017	588 105
1998	200 562	2008	858 407	2018	489 154
1999	260 495	2009	889 574	2019	620 261

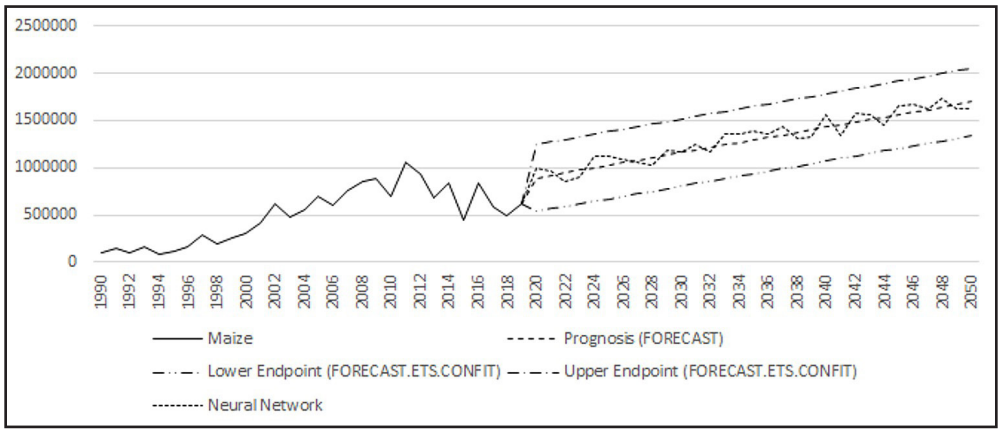
Source: CSO

Table 11: Maize production in period of 1990–2020.

Year	Prognosis	Lower Endpoint	Upper Endpoint	Neural Network
2020	620261	620261	620261	620261
2021	892918	538191	1247645	995787
2022	919649	564920	1274378	969326
2023	946380	591648	1301111	854520
2024	973111	618375	1327847	906091
2025	999842	645099	1354584	1124663
2026	1026573	671821	1381324	1113504
2027	1053303	698541	1408066	1085446
2028	1080034	725257	1434811	1055633
2029	1106765	751971	1461560	1019528
2030	1133496	778680	1488312	1188281
2031	1160227	805385	1515069	1161344
2032	1186958	832086	1541830	1249997
2033	1213689	858782	1568595	1173140
2034	1240420	885474	1595366	1351433
2035	1267151	912159	1622142	1356723
2036	1293882	938839	1648924	1394545
2037	1320612	965512	1675713	1353286
2038	1347343	992179	1702508	1427776
2039	1374074	1018839	1729309	1314321
2040	1400805	1045492	1756118	1330463
2041	1427536	1072137	1782935	1554812
2042	1454267	1098775	1809759	1346256
2043	1480998	1125403	1836592	1570944
2044	1507729	1152024	1863434	1562646
2045	1534460	1178635	1890284	1449037
2046	1561191	1205237	1917144	1656066
2047	1587922	1231830	1944013	1666688
2048	1614652	1258412	1970893	1628380
2049	1641383	1284984	1997783	1737036
2050	1668114	1311545	2024683	1626713

Source: CSO and author´s procession

Table 12: Prognoses of maize production in period of 2020–2050 by means of ETS algorithm and neural network.



Source: CSO and author´s procession

Figure 12: Prognoses of maize production by means of ETS algorithm and neural.

Conclusion

At prediction of results of cereals production trends, it is not possible to expect absolutely exact answers. Models based on perceptron neural networks substitute paradigmatic states of interpolating functions significantly dependent on network configuration (Pattreson, 1996). Processing the same sets of input data and consequent providing with very similar output values clearly prove that neural networks can be used for forecasting of development of certain types of agricultural trends in a similar way as standard statistic prognostic methods.

Furthermore, neural networks are able to generalize solved problems and are more resistant to noise. On the other hand, there is not possible to exactly determine what did an used neural network learnt and, that is why, it is very difficult to find error estimation (Chen, 2005). When any description of observed quantity are available then use of neural network may be an ideal way. Evaluation of tools for prediction may be quite complicated because, in the case of statistic procedures, there are ready heuristics available unlike in the case of neural networks where there is no complete heuristics of methods, modelling over processed data, and configuring parameters for individual network types (Malinovský, 2020, Yao et al., 2017). Within the scope of testing individual parameters, it is impossible to determine some certain network configuration providing with the best results. Quality of prediction carried out by an artificial neural network is affected by lot of factors with potential positive influence on prediction quality (Kabáth, 2009). The factors include number of learning phases, selection of training, testing, and validating set, use of different time series for learning, way of learning, etc. Architectures of neural networks may be easily changed by operators and, so, they enable experimenting with configuration.

Neural networks represent an alternative way to exact statistic (mathematic) methods within the field of forecasting of agricultural trends as well as within other ones.

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Factors Affecting Fast Food Restaurant Image in Peshawar: Moderating Role of Customer Personality Traits

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Abstract

Relating unique identity of product with consumer buying behavior is not so straight forward. Many factors need to be studied in order to investigate this relationship. This study was conducted to see the direct effects of various marketing elements including brand name, service quality, food price and the ambient factors on customer perception about the restaurant image as well as the moderating influence of consumers' personality traits on such relationship. Data was collected from two hundred and forty customers in six well known restaurants of Peshawar in order to examine the hypothesized relationships. The findings of the study support the hypothesized relationship between the study variables and hence all the hypotheses of the study are supported. The study findings particularly the moderating role of personality traits of restaurant customers' in building customers' restaurant perception is of immense importance for academicians in general and restaurant management in particular. The study also presents valuable future research directions which will further this inquiry in future.

Keywords

Restaurant image, service quality, ambiance, personality traits.

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Introduction

Restaurants are playing a strategic role in the economic growth of any country and the fast food sector has become one of the world's largest emerging sector (Anita and Singh, 2007; Baldwin, 2018). The global perspective of restaurant industry unveils that this industry is among the fastest growing sectors (Cravy, 2018). For instance, the global analysis shows that total revenue generated from fast food restaurants in united states amounted to 799 billion dollars at the end of 2017 employing more than 14.7 million people which is 10 percent of the total US workforce and it is projected that only restaurant industry will create 16.3 million jobs by 2027. The total business volume of restaurant industry in UK was worth 73.6 billion euros followed by 50 billion euros in France, 40 billion euros in Germany and 19 billion euros in Netherlands (Cravy, 2018). The Asia pacific market as the expert says is the most fastest growing largest market for restaurant industry with 10 percent growth rate annually which contributed to 1.1 trillion dollars in 2014 and is projected to reach to 1.5 trillion dollar sales between 2015 and 2019 (Cravy, 2018). According to Shaikh and Zahid (2018), Pakistan is ahead of all developing countries in annual spending on eating out which is more than 11.78 billion. They further assert that according to the State Bank of Pakistan, Pakistanis are spending almost 40 percent of their income on readymade food. This all implies that the fastest growing restaurant industry does not only provide jobs and career opportunity to millions of people but also serves as the engine of economic growth as well as positively influence other associated industries which further leads to greater economic growth (Shahzadi e al., 2018). It is also paramount to mention that due to exponential growth in the number of restaurants, the competition among restaurants has risen much than ever. Despite

that there is a sufficient size of loyal customers, a large segment of restaurant customers is price-sensitive (Shaikh and Zahid, 2018). Customers want value for their money and are always in search for more affordable options.

Amid of such competitive environment and to ensure that restaurants remain sustainable and have a sound base of loyal customers who should regularly visit for dinning, it has been stated that customer is the most important marketing tool who influences and assesses the quality and image of the restaurant (Kukanja, 2014). Numerous factors have been stated to influence customers' decision to choose a restaurant. These include both tangible and intangible aspects of customers' consumption experience including service quality, type and quality of food served, location of a restaurant, the prestige of the restaurant, and ambiance etc (Pedraja and Yagüe, 2001). However, extant literature on restaurant also evidences that the importance of various factors in customer selection of a restaurant differs and it depends on particular factors that drive an individual to visit a restaurant (Tichaawa and Mhlanga, 2018; Alonso et al, 2013; Akbar and Alaudeen, 2012). Hence, studying the decision making pattern of restaurant customers considering different restaurant related elements has become the core area of interest for researchers and restaurant management (Tichaawa and Mhlanga, 2018). Among these factors, the restaurant image has been a keen area of interest for researchers since positive image of a restaurant has been predominantly advocated to influence the restaurant customers' decision about choosing a particular restaurant (Aziz and Chok, 2013; Akbar and Alaudeen, 2012; Chung and Kim, 2011).

Aziz and Chok (2013) assert that any image is a combination of impressions and emotions perceived by consumers. Literature on restaurant image identifies numerous factors covering both factual as well as emotional factors. This includes price, quality of service, restaurant environment etc (Chung and Kim, 2011). Besides, literature on marketing and brand management also declares the effects of branding and ambient factors that affect customers' perception about a brand (Keller, 1993). Each of these factors has its own contribution in forming customer perception about the brand. Despite the positive outcome of these various factors, it is however worth to mention that these factors have also been the part of a crucial debate in enhancing restaurant image (Akbar and Alaudeen, 2012). Researchers have identified many other factors that influence customers' image of a restaurant. However scholars have the agreement that difference in factors affecting restaurant image is due to factors such as cultural, ethnic and economic background and hence they have different criteria in determining the restaurant image (Chung and Kim, 2011). Tichaawa and Mhlanga (2018) while comprehensively covering the factors affecting restaurant image conclude that such difference is mainly due to customers' individual characteristics such as economic, demographic as well as personality related factors. They assert that investigating the factors determining restaurant image in isolation to such factors is incomplete.

As guided by marketing literature in general, the role of an individual personality in customers' decision making in many other aspects of life has been a major research debate. Researchers have conceptualized an individual personality as the sum of psychological characteristics that determine a person ability to perform (Tichaawa and Mhlanga, 2018). The two common characteristics of personality in literature are the locus of control (LOC) and self-monitoring. Locus of control means how an individual perceives its external environment with regard to the rewards that he/she has achieved so far (Tichaawa and Mhlanga, 2018). Thus a person with greater internal or external locus of control will behave differently towards the external environment. A consumer with greater internal locus of control is said to have more positive attitude compared to the one having greater external locus of control. Contrarily, consumers with external locus of control (LOC) are more concerned in the business dimensions linked with societal properties and moderates the relation with servicing business (James and Wright, 1993). Similarly, the other aspect of personality, the self-monitoring, is the gauge of motivation used for attitudes and its two forms are high and low self-monitor personalities which differentiate individuals in different processes such as psychological, intellectual and emotional process in different consumers (James and Wright, 1993). As James and Wright (1993) found, various groups differed significantly with different inner emotions, attitudes and expressions. Even studies from psychology evidenced that highly self-monitors are more reactive to situational cue that improves the positivity of the self-images compared to low self-monitor (Krosnick, 1990). Moreover, in restaurant industry too, self-monitoring was found to have a significant moderation effect on customers' minds

(James and Wright, 1993). Hence, we believe that consumers with different personality characteristics (Locus of control Vs Self-Monitoring) may have different response while assessing the effects of various marketing variables on consumers perception about the restaurants they visit.

The current investigation therefore aims to further deepen the understanding of how different personality traits of restaurants' customers moderate the intensity of effect of various determinants of fast food restaurant image. More specifically, the study empirically investigates the moderating effect of personality traits of restaurant customers on the relationship between different factors influencing the restaurant image. The extant literature evidences that restaurant image has been least studied from the perspective of customer personality traits (Tichaawa and Mhlanga, 2018). As indicated by literature and also stated earlier, it is more likely that restaurant customers with different personality traits may behave differently towards the factors affecting image of the restaurant (Tichaawa and Mhlanga, 2018). Hence, this study is an effort to find the impact of marketing variables like restaurant name, food prices, consumer services and atmospherics on restaurant's image with the inclusion of consumer personality traits as a moderating factor.

Research objectives:

1. To investigate the direct effect of various marketing elements (brand name, service quality, food price and the ambient factors) on restaurant image.
2. To investigate the moderating effect of customers' personality traits on the relationship between various marketing elements and restaurant image.

Research questions:

The broader questions this research will address are as under:

1. What is the role of marketing variables (brand name, price, customer service, and ambient factors) in relation to the development of restaurant image?
2. What is the moderating role of different consumer personality traits on the relationship between various marketing variables (brand name, price, customer service, and ambient factors) and restaurant image?

Image is the mixture of complete idea of factual and expressive feelings (Oxenfeldt, 1975). Consumers respond to restaurant's characteristics factually and psychologically (Oh, 1995). According to Chung and Kim (2011), restaurant image is the complete inkling that is supposed by customers. Restaurant image is a vital feature of the consumer satisfaction and a crucial factor for customers' choice of a restaurant. Downs and Haynes (1984) predict that there exists a positive association between restaurant success ratio and its successful image. The center of attention and efforts for a high-quality restaurant is to create the image in the minds of target consumers through advancement in decoration and internal design. Wang (1990) suggests that the visits of target customers to the restaurant depend on the image of particular restaurant in a customer mind. Restaurant image plays an important role to draw consumers and make strong marketplace contained by the competitive atmosphere (Rosenbloom, 1981; Tabassum and Rahman, 2012). To have an aggressive improvement, restaurants should generate distinctiveness in its values and images which should be different and unique from other fast foods restaurant. The trustworthiness of the consumers becomes vital when it is connected with the high-quality image of the restaurant (Rosenbloom, 1981).

Quite earlier, Lessig (1973) found a positive association between restaurant image and consumer's devotion with the name of the restaurant. Investors and owners of the restaurants wash-out billions of dollars for design, building structure and renewal of restaurant to generate a high-quality image in the minds of their potential consumers. One study explores that physical appeal of a name and image of the restaurant in customer mind is significantly correlated with patronage aim (Darden et al, 1983). Restaurant name makes energetic image in consumer's mind. Findings by Zimmer and Golden (1998) suggest that customer frequently use hotel names to clarify the idyllic position.

Restaurant image, being the collection of customers mental perception has got widespread attention and thus numerous factors have been identified that form this mental schema (Tichaawa and Mhlanga, 2018). Researchers have used marketing and brand management literature as theoretical foundation to further towards identification of factors that form restaurant image (e.g., Tichaawa and Mhlanga, 2018). These include brand name effects, price of food served, customer perception of service quality and the ambient factors (e.g., Tichaawa and Mhlanga, 2018). These factors and its association with restaurant image are discussed

hereafter. Further, as advocated in the psychology literature, the consumers'' personality traits (Locus of control and Self-monitoring) have been found to influence an individual behavior (Krosnick, 1990). Thus, the next section also highlights the moderating influence of restaurant customer personality traits on how the various marketing variables influence the restaurant image.

Linkage between brand name and brand image

Brand name is one of the fundamental components of brand building process and hence the brand equity (Keller, 1993) Brand name reflects the collection of knowledge about the product (Richardson et al., 1994) and is one of the basic significant factors which captures the main theme or primary association of a product (Keller, 1993). According to Keller (1993), companies and marketing professionals must be very cautious about naming their products since successful brands among many other factors share a good strategic brand name. He further elaborates that a strategic brand name should be catchy, short, and repetitive. He illustrates few such renowned brand names as "Kit-Kat, Coca Cola, Bizzinet etc. Further, a good brand name resonates the product quality. In other words, the brand name should be meaningful and should reflect the benefits of the product such as Comfort, Tough, Executive etc. (Keller, 1993). Indeed, a good strategic brand name has been advocated to build greater positive brand equity by forming greater awareness as well as positive perception and image associations (Keller, 1993). The customers' quality perception of the product has been often found to relate positively with brand name (Keller, 1993). Olshavsky (1985) study on retail store image recommends that positive restaurant image in customer's memory depends on valuable brand name. Even much earlier, Lessig (1973) found a close positive relationship between restaurant image and consumer's devotion and commitment with the name of the restaurant. Hence, the study hypothesizes that stylish and good restaurant name would have a positive relationship with restaurant image.

Price and brand image

Price is much commonly used as a differentiation tool such that customers relate high price with high quality (Keller, 1993). The knowledge about price has been stated to be one of the top behavioral consideration in the last four decades and hence a strategic tool for marketing professionals. (Dib and Alhaddad, 2014). Price has been one of the important marketing mix element (Wise and King, 1973). Moreover, price is an important selection factor for consumers (Agárdi and Bauer, 2000). It is recognized that consumers encode the price information into memory in various representative forms. Even the amount customers pay has a strong effect on customers' assessment of the product quality, thus equating high price with premium quality and vise verse. Price has also been stated to influence customer awareness (Kenesei and Todd, 2003) which refers to the ability of customers to recall the price paid (Monroe, 2003). Kenesei and Todd (2003) further elaborate the concept of price awareness by stating that price awareness can be in the form of a price paid by customer, intensity of price search and thirdly the intensity with which shoppers compare prices.

Akbar and Alaudeen (2012) reported that price of a brand extensively affects consumer perception about the product quality. Fornell (1994) reported that customer satisfaction can be obtained by giving them a positive best favorable price for the reason that consumers always compare the prices with the quality of products and services particularly in shopping and expensive products. Moreover, research by Tichaawa and Mhlanga (2018) confirms that consumers perceive price level as an instrument for improving the brand image such that a higher brand price is perceived by customers as better brand image. Hence, this study assumes that restaurants with high meal prices will also generate consumers' positive perception of these restaurants.

Customer service and brand image

The crucial issue of the hotel and restaurant industry is the quality of service to its customers (Chung and Kim, 2011). The service quality literature reveals that customers remain more sensitive to the service elements and their perception about the quality of the service offered by an organization significantly influence their buying behavior (Keller, 1993). The service quality has been found to be one of the crucial factors that lead to greater customer satisfaction (Chung and Kim, 2011). According to Tichaawa and Mhlanga (2018), quality of customer service is the major aspect of consumer's overall happiness and satisfaction. Further, there has been abundance of literature evidence on the favorable outcome of customer satisfaction on company brand equity (Tichaawa and Mhlanga, 2018) of which brand image is one of the significant factor (Keller, 1993). Aydin and Ozer (2005) conclude that high service quality is one of the central factor to combat competitors in the service market and has a direct effect on customer satisfaction as well

as customer trust. This also implies that a customer is satisfied when he / she gets more than what he expected before purchase. Even the performance of the service provider is mainly judged by the service quality. Besides, there are numerous studies in food sector confirming a close significant relationship between service quality and customer satisfaction. Service quality has been measured in terms of food quality, physical environment, employee service (Dutta et al., 2014). For instance, Ryu et al. (2012) stressed on the significance of quality of food as a measure of customer satisfaction in food sector. According to Qin and Prybutok (2009), food quality in restaurants has a significant positive effect on customer satisfaction. Satisfied customers have more positive word mouth for advocating the organization and thus it is believed that customers favoring a restaurant on its service quality would also have a positive image of the restaurant.

Linkage between ambient factors of restaurants and brand image

Developing an environment of right mood is a crucial factor in customer satisfaction particularly in food sector (Ariffin et al., 2011; Mattila and Wirtz, 2001; Basera et al., 2013). Even restaurants are using the ambiance factors as a tool of competitive advantage which implies that perception about the quality of food is also influenced by the atmospherics in which customers are served (Zeithaml and Bitner, 2003). It has been argued that restaurant providing a pleasing ambiance attracts more customers to stay and spend money compared to those not providing such ambiance. Such ambiance includes everything such as interior of a restaurant, building color and design, decoration, exterior appearance, room temperature, walls texture, background music, lighting, and aroma etc. (Omar et al, 2011; Zeithaml and Bitner, 2003).

Levy and Weitz (2009) suggest that restaurant's atmospherics are referred to the main characteristics that endeavor and strengthen the restaurant atmosphere with the mixture of diverse signs such as lights, paints, melodies, and fragrance. What customer eats, drinks and feel are deeply prejudiced by senses of tastes and smell. Feldman (2009) reported that a normal person sense of taste is able to detect more than one thousands different odors and those persons have strong abilities to simply remember odors connected with lengthy forgotten events. Therefore, if a consumer is not satisfied with an experience to some restaurant, that consumer might be highly memorizing it every time when he / she sniffs that fragrance. From an imaginative point of view, paints of restaurant have the capability to revoke thoughts, expressions, and behavior of different customers (Tichaawa and Mhlanga, 2018). Since the coloring and painting attract consumer`s mind, therefore it may create both the positive or negative feelings. Similarly, lighting appears in a multiplicity of shapes and is used for many purposes like background lighting, task lighting, attractive lighting, vital lighting, and drawl lighting. When the restaurant atmosphere is bright enough, customers are more able to examine and touch the products in the restaurants (Feldman, (2009). Similarly, Mattilia and Wirtz (2001) predict that different sound melodies are a significant part in improving overall customer thoughts and emotions. Research findings of Ryu and Jang (2008) also evidence that restaurant ambiance such as aroma, music, temperature etc. has a significant effect on the emotional responses of restaurant customers which also influence their post-dining behavioral intentions. Hence, it is postulated that restaurants with good ambiance would help customers develop good feelings and emotions and hence would also develop positive associations about the restaurant.

Factors affecting fast food restaurant image: consumers' personality traits as a moderator

Individual's personality has been a major research debate in many fields including science, arts and creativity. Personality of an individual is the sum of psychological characteristics that determine a person ability to perform (Tichaawa and Mhlanga, 2018). The two common characteristics of personality in literature are the locus of control (LOC) and self-monitoring (James and Wright, 1993; Rotter, 1966). Much earlier, Rotter (1966) gave the concept of locus of control for the very first time in his research study from societal learning theory, and subsequently gained a very vital and positive attention towards behavioral researches. These concepts have been modified and developed largely in many fields like service business (James and Wright, 1993) health sectors (Wallston and Wallston, 1976) and finance sector (Duxbury et al., 1996). First, theory of locus of control (LOC) was produced in psychology literature as an individual typology and then practically applied on managerial level and specifically in the business management fields like restaurant sectors (Hodgkinson, 1992). Rubin and Rubin (1992) research reveal that locus of control became an important psychosomatic ancestor to how

and why persons correspond interpersonally. They suggest that locus of control can be internal as well as external.

Consumers having greater internal locus of control are more in self-controls and have more positive serviceable attitudes and are more likeable to come back to restaurants or repurchasing abilities than consumers with greater external locus of control (James and Wright, 1993). Consumers with external locus of control (LOC) are more likeable to be concerned in the business dimensions linked with societal properties and moderates the relation with servicing business (James and Wright, 1993). The consumers of service organizations like restaurants may be better if a customer thinks of himself or herself as complete employ of the particular restaurant, and has control during the dealings (Tichaawa and Mhlanga, 2018).

The other dimension of personality trait, self-monitoring, is a gauge of the motivation used for attitudes and forecasts the way that attitudes lead by actions. The two forms of self-monitoring are high and low self-monitors which differentiate individuals in different processes like psychological, intellectual and emotional processes (James and Wright, 1993). They found different results for groups with different inner emotions, attitudes and expressions. Some research findings of psychology can be relevant to service related behaviors too. For instance, Krosnick (1990) found that highly self monitors are more reactive to situational cue that improves the positivity of the self-images compared to low self-monitors. Even in restaurant industry, self monitoring was found to have a significant moderation effect on customers' judgment (James and Wright, 1993). Johar and Sirgy (1991) reveal that efficiency of restaurant image in opposition to instructive marketing can differ depending upon a variety of viewers' factors including self-monitoring, where highly self-monitors react more positively to restaurant image and societal uniqueness and lower self-monitors react more positive to informative (functional) demands (Krosnick, 1990). Thus, it is believed that consumers with different personality characteristics (Locus of control Vs Self-monitoring) will have different response for the effects of marketing variables on consumers perception about the restaurants they visit.

Theoretical framework

Based on the literature review, the following theoretical framework of the study is deduced (Figure 1).

Hypotheses

Based on the literature discussion, the following hypotheses of the study are proposed.

Direct relationship:

H_1: There exists a significant positive relationship between brand name and restaurant image.

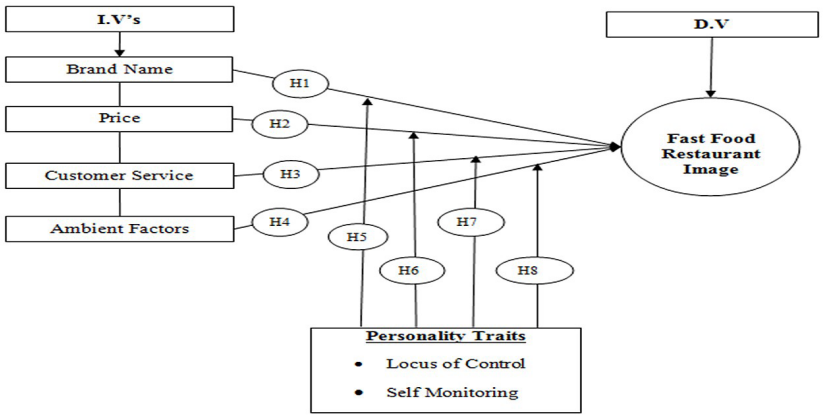
H_2: There exists a significant positive relationship between food price and restaurant image.

H_3: There exists a significant positive relationship between customer services and restaurant image.

H_4: There exists a significant positive relationship between ambient factors and restaurant image.

Moderating hypotheses:

H_5: Consumers' personality traits (Locus of control and Self-monitoring) would have a significant moderating effect on the relationships between



Source: own editing, 2020.

Figure 1: The theoretical framework of the study.

brand name and restaurant image.

H_6: Consumers' personality traits (Locus of control and Self-monitoring) would have a significant moderating effect on the relationships between food price and restaurant image.

H_7: Consumers' personality traits (Locus of control and Self-monitoring) would have a significant moderating effect on the relationships between customer services and restaurant image.

H_8: Consumers' personality traits (Locus of control and Self-monitoring) would have a significant moderating effect on the relationships between ambient factors and restaurants image.

Materials and methods

Data and sampling

In order to test the hypothesized linkages between the study variables, data was collected from fast food customers in six well-known fast food restaurants of Peshawar, the provincial capital city of Khyber Pakhtunkhwa. To ensure the validity of the data as well as generalizability of the study findings, six out of nine well established major fast food restaurants were selected, thus representing more than sixty six percent of the total number of fast food restaurant in the capital city. Hence, sufficient representation of the fast food sector in the provincial capital was ensured. To further ensure the generalizability and greater representation of the sample, only those six fast food restaurants were selected which were believed to have greater diversity in terms of customers. Hence a judgmental sampling approach was adopted to select the restaurants. Prior approval of the restaurant was sought and with the help of restaurant manager in each restaurant, questionnaires were distributed to consumers who visited the restaurants for dinning. In each of the six restaurants, forty questionnaires were distributed that led to a total sample size of two hundred and forty restaurant customers. From each restaurant, forty usable questionnaires were returned and hence the response rate was 100 percent.

Study measures

Review of existing conceptualization guided that the measurement of the study variables could reliably be attained through the already established validated measures. Hence, all the study measures including restaurant name (brand name), service quality, restaurant image, and personality type and restaurant ambience were adopted from established literature (Eliwa, 2006). To make the questionnaire more understandable, every item of the questionnaire was typed in both English as well as Urdu (National Language). The first section of the questionnaire consisted of information about restaurant customers' demographics including age of customers, gender, marital and professional status and finally income level. The second section was containing items related to various study variables. The restaurant image, a dependent variable, was measured using six items such as "I usually use this restaurant as my first choice'; "This restaurant has a unique perception in my mind"; "This restaurant is different from other restaurants". Restaurant brand name was measured using eight items such as "Restaurant brands are familiar to me"; "Appropriate brand name of the product enhances the image of the restaurant"; "For better restaurant image good product brand name is mandatory"; "A well-known product brand name creates the value of restaurant in the mind of customer". Customer service at the restaurant was measured with the help of six items such as "Customer service of the restaurant enhances image of the restaurant"; "This restaurant has an excellent reservation system"; "Overall customer service of the restaurant is good". Similarly, customer perception about price of the food and services was measured using five items including "Price of the restaurant products is reasonable"; "Favorable products prices enhance the restaurant image"; "High product prices improve the image of the restaurant at customer mind". Restaurant ergonomics / ambient factors were measured using eight items such as "This restaurant is situated in an excellent geographical location with car parking facility"; "This restaurant has an excellent physical appearance"; "The restaurant internal environment is neat and clean". Lastly, the personality traits of customers (Locus of Control) was measured with the help of five items such as "When I make plans, I am almost certain that I can make them work"; "It is impossible for me to believe that chance or luck plays an important role in my life". The other dimension of personality traits (Self-Monitoring) was measured using five items such as "I find it hard to imitate the behavior of others"; "At parties and social gatherings, I do not attempt to do or say things that others will like"; "I rarely need the advice of my friends to choose restaurant". All the study measures were measured using five point Likert scale ranging from strongly disagree (1) to strongly agree (5).

Data analysis

The collected data was analyzed using SPSS (v.20). Initially descriptive and reliability analysis were carried out followed by hypotheses testing for direct and moderating relationship using the Baron and Kenny (1986) regression analysis approach.

Results and discussion

The demographic profile of the respondents shows that male respondents were one hundred and forty four out of two hundred and forty comprising of sixty percent of the total sample compared to ninety six female respondents that comprised of forty percent of the total sample size. The age-wise analysis of the sample respondents was as follow: Participants in the age bracket of 20-25 years represent 48 out of 240 members that depicts 20% of the total sample. Sample respondents with ages from 26-30 years and 31-35 years were each twenty five percent respectively. Participants' having ages of 36-40 years and 41-45 years remained 16.9 percent and 13.1 percent respectively. Further, restaurant customers with salary level below Rs. 15000, Rs. 16000-30000, Rs. 31000-45000 and above Rs. 46000 remained 21.9%, 18.1% 17.5% and 42.5% respectively.

Reliability analysis

The collected data on various measures of the study was checked for internal consistency (Table 1). The cronbach's alpha coefficient values for restaurant image, brand name (restaurant name), price, customer service, ambient factor and personality traits were found to be 0.83, 0.83, 0.82, 0.79, 0.81 and 0.84 respectively as evident from Table 1.

Variables	Cronbach's α	No of Items
Brand Name	.83	5
Food Price	.82	5
Customer Services	.79	5
Ambient Factor	.81	5
Restaurant Image	.83	5
Personality Traits	.84	6

Source: Source: own editing, 2020.

Table 1: Reliability of measuring instrument.

Hypotheses testing: direct and moderating relationships

To test the hypothesized relationship (direct and moderation effects), the Baron and Kenny (1986) statitical technique was applied. To test the direct relationship between brand name (restaurant name) and restaurant image (H1) as well as the moderating effect of consumers' personality traits on this relationship (H5), the Baron and Kenny (1986) regression analysis was run. As evident from table 2 below (Step 1), the brand name (restaurant name) was found to significantly affect consumers' image of restaurant (R-Square = 0.786, $p<0.05$). The R square statistic shows that brand name has a significant effect on restaurant image amounting to 78.6 percent, thus confirming a direct relationship between brand name and restaurant image and hence H1 is supported. Further, the moderation effect was observed by looking into the interactive effects of brand name and personality traits on restaurant image. Results of the analysis (Step 4, Table 2) found that 69.4% variations in restaurant image was explained by multiplied variables i.e. brand name and personality traits. Result depicted that the value of R square increases from 0.618 (Step 1) to 0.694 (Step 4) and the beta weights are

Steps	*R*	ΔR^2	*F*	*B*	*T*	*Sig*
Step 1						
BN(IV) → RI (DV)	.786	.618	255.592	.786	15.980	.000
Step 2						
BN(IV) → PT(MV)	.862	.744	458.610	.862	21.415	.000
Step 3						
PT(MV) → RI (DV)	.862	.743	457.794	.862	21.396	.000
Step 4						
BN+BN*PT → RI(D.V)	.618	.694	177.930	.817	6.230	.000

Note: BN: Brand Name; PT: Personality Traits; RI: Restaurant Image
Source: own editing, 2020.

Table 2: Regression analysis summary for brand name and restaurant image with moderation of personality traits (N=240).

also increased implying that personality traits significantly moderate the relationship between brand name and restaurant image. Hence, H5 is also supported.

To test hypothesis two (H2) stating the direct linkage between price of meal served at the restaurant and restaurant image, as well as the moderating effect of consumers' personality traits on this relationship (H6), the Baron and Kenny (1986) regression analysis (Table 3) found that price of meal has a significant relationship with restaurant image (Step 1) (R-Square = 0.787, $p < 0.05$). As revealed by the R-square statistic, price of meal explains 78.7 % variation in restaurant image, thus confirming a direct relationship between price of meal and restaurant image and hence H2 is supported. Moreover, the interactive effects of food price and personality traits on restaurant image (as can be seen in table 3) was also found significant with increase in R-square value from 0.619 (Step 1) to 0.694 (Step 4) proving that personality traits of consumers interacts with price that significantly moderates the relationship of price and restaurant image. Hence, H6 is also supported.

Table (4) presents the analysis of direct relationship between customer service at the restaurant and the restaurant image (H3) as well as the moderating effects on it by customer personality traits (H7). Regression analysis for direct relationship between customer service and the restaurant image confirmed a significant relationship (Step 1) (R-Square = 0.79, $p < 0.05$). The R-square statistic shows that there exists a significant relationship between customer service and restaurant image amounting to 79 percent, thus supporting H3. Further, the combined effect of customer service and personality traits on restaurant image (Step 4) was also found significant such that R square increased from 0.624 (Step 1) to 0.698 (Step 4) and the beta weights also increased (0.79 to 0.80) implying that personality traits also significantly moderates the relationship of service quality and the restaurant image. Hence, H7 is supported.

Steps	*R*	ΔR^2	*F*	*B*	*T*	*Sig*
Step 1						
P(IV) → RI (DV)	.787	.619	257.072	.787	16.033	.000
Step 2						
P(IV) → PT(MV)	.867	.751	477.625	.867	21.855	.000
Step 3						
PT(MV) → RI (DV)	.862	.743	457.794	.862	21.396	.000
Step 4						
P+P*PT → RI(D.V)	.619	.694	178.347	.810	6.207	.000

Note: P: Price; RI: Restaurant Image; PT: Personality Traits
Source: own editing, 2020.

Table 3: Regression analysis summary for price and restaurant image with moderation of personality traits (N=240).

Steps	*R*	ΔR^2	*F*	*B*	*T*	*Sig*
Step 1						
CS(IV) → RI (DV)	.790	.624	262.701	.790	16.208	.000
Step 2						
CS(IV) → PT(MV)	.870	.756	489.841	.870	22.132	.000
Step 3						
PT(MV) → RI (DV)	.862	.743	457.794	.862	21.396	.000
Step 4						
CS+CS*PT → RI(D.V)	.624	.698	181.098	.802	6.164	.000

Note: CS: Customer Service; PT: Personality Traits; RI: Restaurant Image
Source: own editing, 2020.

Table 4: Regression analysis summary for customer services and restaurant image with moderation of personality traits (N=240).

Steps	*R*	ΔR^2	*F*	*B*	*T*	*Sig*
Step 1						
AM(IV) → RI (DV)	.790	.624	262.335	.790	16.197	.000
Step 2						
AM(IV) → PT(MV)	.870	.756	489.903	.870	22.134	.000
Step 3						
PT(MV) → RI (DV)	.862	.743	457.794	.862	21.396	.000
Step 4						
AM+AM*PT → RI(D.V)	.624	.697	180.331	.802	6.31	.000

Note: AM: Ambient Factors; PT: Personality Traits; RI: Restaurant Image
Source: own editing, 2020.

Table 5: Regression Analysis Summary for Ambient factors and Restaurant Image withmoderation of Personality Traits (N=240).

Analysis for hypothesis four and eight (H4 and H8) covering the direct relationship between ambient factors and restaurant image (Table 5) was found significant (Step 1) with regression coefficient value of 0.79 implying that ambient factors bring 79% change in building customers' perception about the restaurant. Hence, hypothesis four postulating a direct relationship between ambient factors and restaurant image is supported. The moderation effect analysis shows that the interaction of restaurant ambient factors and consumers' personality traits (Steps 4) has a significant positive effect on restaurant image amounting to 69.7%. Further, the value of R square increases from 0.624 to 0.697 and the beta weights are also increased significantly from 0.79 to 0.80 implying that H8 is also supported.

Conclusion

The findings of this study are two fold; one, that different marketing factors including brand name, price of food served, quality level of customer service and ambient factors were found to have a significant effect on customer image of the restaurant they choose, and secondly; whether different personality characteristics of such customers moderate these relationships. Hence, besides, the factors affecting restaurant image, another interesting and novel findings of this study is the moderating influence of restaurant customer personality traits on the effects of various marketing variables (customer service quality, food price, brand name and ambiance) on restaurant image. All the moderating hypotheses (H5, H6, H7 and H8) were supported such that the value of R-square increased in all the moderations implying that customers' personality traits did influence the relationship among various marketing variables and restaurant image. The findings of this study confirm all previous studies stating a significant positive role of various marketing variables used in this study. For instance, Mhlanga and Tichaawa (2016) empirically found that good quality customers' service, food quality and good ambiance are among the key factors influencing the customer's choice of a restaurant. Similar findings are also reported by Akbar and Alaudden (2012) who found that consumers prioritize restaurants first on the basis of food quality, then trustworthiness and followed by service quality, food price, restaurant environment and finally the location of restaurant. Indeed, it would be safe to conclude that such findings are almost very general (e.g., Josiam and Monteiro, 2004; Mhlanga and Tichaawa, 2016) with the exception that few researchers posit that the type of restaurant also influence customers perception about these marketing variables (Hensley and Sulek, 2007; Kim and Moon, 2009). For instance, Kim and Moon (2009) assert that due to difference in customers' expectations and perceptions about their dining experiences, their criteria for selection of restaurants may also vary when they are deciding where to go and eat. This is also paramount to mention that Kim and Moon (2009) views also somehow matches with the personality traits proposition as used in this study. That is, all marketing variables earlier found to have influence on customers' selection of a restaurant may vary and it depends on customers' personality type as advocated by other marketing (Tichaawa and Mhlanga, 2018) and psychology researchers (Krosnick, 1990; James and Wright, 1993).

Regarding the moderating role of customers' personality traits, the study finding implies that customer personality has a crucial role

in the selection of factors that determine customers' restaurant choice as claimed by Tichaawa and Mhlanga (2018) and psychology researchers Krosnick (1990) and James and Wright (993). Tichaawa and Mhlanga (2018) has very rightly said that difference in factors affecting restaurant choice is mainly due to difference in customers' individual characteristics such as economic, demographic as well as personality related factors. The moderating effects of personality factor in this study also substantiate this claim of Tichaawa and Mhlanga (2018) that it is incomplete to investigate the factors determining restaurant image in isolation to cultural and personality factors. Such findings have worthwhile implications for restaurant management which suggest that it is not merely the price, food quality or ambient factors that affect customers' choice of a restaurant, rather personal characteristics of customers also deserve much attention.

It is also paramount to mention that the significant effect of various marketing factors as found in this study including food price, brand name, food quality etc. have enormous implications for the supplies that restaurant industry gets from various suppliers including agriculture industry (Jekanowski, 1999). The growth in expenditures of fast food is evident from the food purchased by the fast food industry. As revealed by Jekanowski (1999), the growth of multinational fast food restaurants can have a significant effect on various segments of the agriculture marketing system. For instance, the annual consumption of Pizza Hut milk consumption is over 3.2 billion pounds, approximately 2.5 percent of the total annual milk production. Similarly, it required approximately 17.5 million pounds of cheese amounting to fifty percent of total cheese production in United States. Same is the case of McDonald which used more than 644 million pounds of beef and 1.35 billion pounds potato representing 2.5 and 3.2 percent of the total annual production of United States (Jekanowski, 1999). Agriculture industry supplies major raw ingredients to food industry which can significantly increase the value added through food industry (Gouk, 2012). This linkage between agriculture sector and food industry covers many other businesses related to food processing, conversion, preparation and preservation and packaging (Gouk, 2012). With the change in lifestyle such as faster pace of work, shortage of time and greater demand of convenience in food as well as other factors including low cost, customers' taste preference and new brands, the fast food industry is growing at a very high rate across the globe even at a faster rate than the annual GDP growth in some countries (Wang, Wang, Xue and Qu, 2016). With the changes in consumers' life styles, increased population size, increased household income and increased leisure and recreational activities, the fast food industry has long lasting positive consequences for the economic growth. This also indicates that keeping in view the greater potential of fast food industry for economic growth as well as its linkage with agriculture sector, a major economic contributor in Pakistan economy (Rehman, Luan, Abbas, Chandio, Hussain, Nabi and Iqbal, 2015), there is a need for major agricultural reforms such as taxation system reforms, and better marketing systems for agricultural inputs and commodities. Such reforms will ensure that customers of fast food industry get best quality food, as well as consistent supply of required amount of agricultural products.

Recommendations and future research direction

In the light of study findings, the consumer personality traits, a moderating factor and other marketing variables studied in this study can be considered as fundamental in order to build up a good restaurant's image. It means the overall restaurants efficiency could be improved. It is necessary to develop such environment or atmosphere where clients are pleased and satisfied with the best services they may get from that particular restaurant. In this fashion, clients become faithful with that restaurant and their regularity of visits to the same restaurant will more likely increase. It is also highly recommended that customer personality traits also play a significant role in how various marketing variables such as price, food quality, service quality ambiance etc affect customers' choice of a restaurant. Hence, due attention should also be given to personality of restaurant customers. Though the study is a comprehensive endeavor to investigate how consumers' personality traits (Locus of control and self-monitoring) exert influence on the relationship between various important factors (e.g., brand name, service quality, ambient factors etc.) and restaurant image, the underlying mechanism of such relationship may be further studied by including other mediating variables so that these relationships could be more deeply investigated. For instance, how the ambient factors stimulate sensory pleasure and affect the customer satisfaction which in turn may lead to positive restaurant image. Moreover, the study model was tested in six well known restaurants of Peshawar which can be further studied in much detail by extending it to more prestigious hotel chains

of the country. Moreover, greater generalizability of the study findings could be obtained by studying the determinants of restaurant image in a more socially and culturally diverse setting. In the same vein, similar studies can be conducted in other service sectors like insurance and financial services organizations.

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Sentiment Analysis in Agriculture

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Abstract

Sentiment analysis is currently the most actively researched topic in the field of natural language processing, however, despite it being such a powerful tool, it is not very widely used in the agrarian sector. This research focuses on the discovery and analysis of scientific literature related to Sentiment analysis in agriculture, to provide an overview of how and where Sentiment analysis is used in the agrarian sector and which methods are most commonly used. This article also discusses which applications of Sentiment analysis yield the most benefits and suggests a direction for future research.

Keywords

Sentiment analysis, agriculture, opinion mining, natural language processing, text mining.

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Introduction

The goal of this research is to discover and analyze literature focused on the application of Sentiment analysis in agriculture, to map the current state of research, and ultimately, to suggest a direction for future research conducted on this topic. The first part of the article is covering the background of the observed topic and asserting its importance, as well as acknowledging the previous work of other researchers. Afterward, the focus shifts towards a definition of a methodology for the discovery of information sources, their analysis and evaluation. Following that, the article communicates the results of the analysis and then finally concludes with an evaluation of research done on the observed topic and suggestions for future work. The research is purely focused on the analysis of literature, which is dealing with the application of sentiment analysis agriculture and farming. Applications of sentiment analysis in fields closely related to agriculture, such as food quality and food production, are not covered in this research.

ICT and agriculture

The introduction of ICT in the agrarian sector has a tremendous transformational character throughout the whole industry and leads to increased agricultural efficiency and reduced environmental impact, which in turn increases the food quality. (Heege, 2013). This is hardly surprising, considering that agriculture has always been highly dependent on precise information and efficient communication (McNamara et al., 2011). Also, in addition to improvement in farming efficiency and empowerment of farmers, increased adoption of ICT in agriculture brings new ways to collect valuable data, which may be then used for further research (Daum, 2018) as well as improvement of the management processes using information technologies (Muhammad et al., 2019). ICT usage in communications at all stages of manufacturing and commerce in agrarian sector, like other types of economic activity, leads to increase of effectiveness, measured by value added and connected economic indicators (Bilan et al., 2019). Beyond that, digital technology also dramatically increases the quality of life in rural regions for individuals and enterprises (Shaibu et al., 2018; Toomsalu et al., 2019), being in many cases one of the crucial factors of the rural communities’ development (Kostiukevych et al., 2020). Clearly, there is potential in exploring new ways of integrating ICT into agriculture, but it is necessary to point out that farmers are hesitant adopters (Pierpaoli et al., 2013), and therefore the benefits of such new methods must be proven and explained thoroughly (Chukwunonso, 2012).

Sentiment analysis and opinion mining

Since the web changed from “read-only” to “read-write”, its enthusiastic users started to create a base

of collective knowledge through social networks, blogs, wikis, online communities, and other types of web media. Meanwhile, engineers and computer scientists started to apply text classification methods, such as opinion mining and Sentiment analysis on the user-produced content (Cambria et al., 2013). Sentiment analysis is described as a discipline focused on the analysis of people's opinions, sentiments, evaluations, appraisals, attitudes, and emotions towards products, services, organizations, and other entities with methods of natural language processing (Liu, 2012). The term "sentiment analysis" was first used by (Nasukawa and Yi, 2003) and the term "opinion mining" was introduced by (Dave et al., 2003) and both of them are being used interchangeably by academics (Saberi and Saad, 2017).

Sentiment classificators use human-generated text (words, phrases, or whole documents) as an input and determine the sentiment polarity of the given document to be either positive or negative. Modern sentiment classificators are able to distinguish neutral sentiment as well. Sentiment analysis is mainly used in the fields of marketing, sociology, and politics (D'Andrea et al., 2015).

Currently used approaches of Sentiment analysis can be categorized into the following three groups (Sharma et al., 2019):

- **Lexicon based approach** determines sentiment from the semantic orientation of words and phrases. This approach requires a dictionary, containing a selection of words with their positive and negative sentiment values (Jurek et al., 2015). This makes the approach more difficult to implement in the environment of less spoken languages, where such dictionaries are not yet widely available.
- **Machine learning approach** applies machine learning algorithms such as Naïve Bayes, Maximum Entropy, etc., to determine sentiment through linguistic features. Both supervised and unsupervised methods can be used, although supervised learning is preferred, given that a sufficient quantity of labeled input documents is available (Walaa et al., 2014).
- **Hybrid approach** combines the lexicon-based approach and machine learning approach for increased performance (Ahmad et al., 2017).

Related work

A similar paper titled "A survey of the applications of text mining for agriculture" exists (Drury and Roche, 2019) however, it is focused broadly on reviewing applications of data collection and text mining methods in agriculture in general. A small section of the mentioned paper is dedicated to Sentiment analysis in agriculture; however, the topic is covered quite briefly and only a few examples are provided. This research on the other hand focuses specifically on applications of Sentiment analysis in agriculture and aims to review all available literature related to this topic.

Materials and methods

This research is going to apply methods of conventional literature review, similar to those in (Drury and Roche, 2019), however, it is going to cover a significantly larger volume of topic-specific literature. Unlike in (Drury and Roche, 2019), the reviewed publications are not going to be discussed in depth individually, but instead, their methodologies will be extracted in a standardized way proposed by the author, and the following discussion is going to focus on the state of research in the topic as a whole.

The first step is going to be finding a sufficient quantity of relevant literature for the topic of Sentiment analysis in agriculture. Once the list of publications is compiled, then all of the listed publications are going to be reviewed and grouped by proposed approaches, objects of analysis and dates of publication, to determine the current state of research in Sentiment analysis in agriculture. Publications are going to be reviewed from the oldest to the newest, to maintain continuity.

Finally, a synthesis of information obtained from the reviewed publications is going to be used in making suggestions for further research.

Methodology of discovering literature

The literature is going to be searched for via Scopus and Google Scholar databases. Boolean search operators are going to be used to search for specific as possible.

- Scopus database query: TITLE-ABS-KEY (("sentiment analysis" OR "opinion mining ") AND agriculture);
- Google Scholar query #1: "sentiment analysis" AND agriculture;

- Google Scholar query #2: “opinion mining” AND agriculture.

Google Scholar, unfortunately, does not support brackets, therefore “sentiment analysis” and “opinion mining” have to be queried separately. Results of all the queries are going to be filtered manually according to the criteria defined by the author in Table 1, in order to exclude irrelevant literature.

Requirements for literature	
Date of publication:	2010-2020
Type of publication:	Scientific article, Book, Thesis, Conference proceedings, Project report
SJIF:	Any or N/A
Topic:	Application of sentiment analysis/ opinion mining and agriculture

Source: own

Table 1: Requirements for publications compiled by the author, in order to exclude irrelevant literature.

Methodology for literature review and analysis

Individual articles are going to be reviewed thoroughly, to extract methods and approaches used by researchers working on Sentiment analysis in agriculture. Firstly, a set of characteristics for the description of methodology in Sentiment analysis research should be defined. According to a consensus amongst researchers in the field, the process of Sentiment analysis consists of the following steps:

- Obtainment of input data;
- Pre-processing of input data;
- Application of Sentiment analysis model;
- Model evaluation.

These methods used, to accomplish these steps, are going to be extracted from the reviewed articles and are going to serve as a base set of characteristics for evaluating applications of Sentiment analysis in agriculture. In addition to this, the language of input data and results of the model evaluation will be extracted from the articles as well. Therefore, the final set of characteristics, which will be used to describe each of the articles is going to look as follows:

- Input data [Type and source of the input data.];
- Input language [Original language(s) of the input data.];
- Pre-processing [Methods used for data pre-processing, if mentioned.];
- SA algorithm [Algorithm, model, or tool used to perform the actual sentiment analysis.];
- Model Evaluation [Methods used for model evaluation, if mentioned.];
- Model Accuracy [If provided.].

Note: It was originally intended to include whether the authors of the peer-reviewed articles considered their research to be successful or not, but this was omitted because it was shown that all authors considered their research to be successful and worthy of further development.

Therefore, it was decided, that only purely methodologic information will be included in the results.

Methodology for the state of research determination

Quantitative and qualitative methods are going to be combined, to describe the current state of research. Firstly, statistical analysis will be used to determine the distribution of reviewed articles per year of publication, applied approach of sentiment analysis, and object of study. Synthesis of results combined with a qualitative evaluation of the results will then be used in conclusion, to describe the current state of research and to suggest the direction for future work.

Results and discussions

A total of eleven publications has been found via the proposed methodology of literature discovery and are now listed in Table 2.

Figure 1 shows a trend of increase in publications on the topic of Sentiment analysis in agriculture over the past few years. The most productive so far was the year 2018 with a total of 5 publications on the topic.

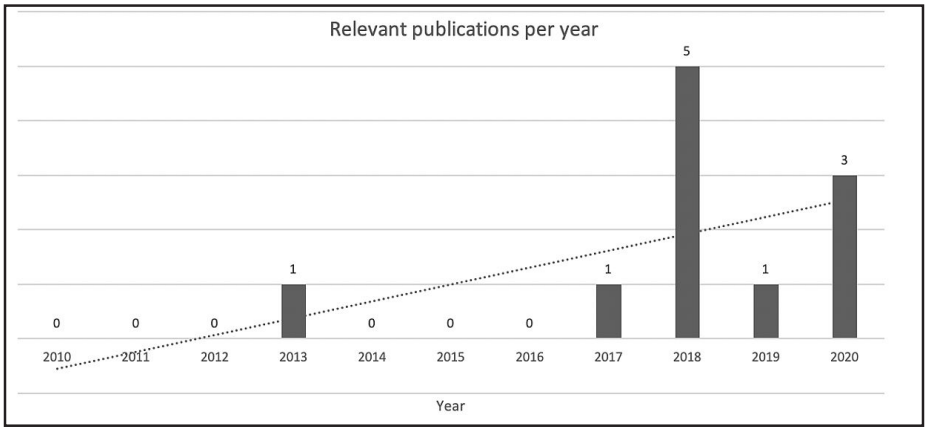
As shown in Figure 2, machine learning is the most commonly used approach to Sentiment analysis in agriculture, while the lexicon-based approach only appears in the form of NRC Sentiment analysis library for R, and hybrid approaches are ignored completely. All of the publications focus on the three following objects of analysis:

- The sentiment of farmers towards agriculture;
- The sentiment of the general public towards agriculture;
- The sentiment of mainstream media towards agriculture.

Year	SJIF	Paper title	Journal/publication type	Author
2020	3.84	Drivers and challenges of precision agriculture: a social media perspective	Precision Agriculture	(Ofori and El-Gayar, 2020)
2020	2.825	A novel text-based framework for forecasting agricultural futures using massive online news headlines	International Journal of Forecasting	(Li et al., 2020)
2020	0.53	Twitter Users Opinion Classification of Smart Farming in Indonesia	IOP Conference Series: Materials Science and Engineering	(Salim et al., 2020)
2019	N/A	Sentiment Analysis of English-Punjabi Code-Mixed Social Media Content for Agriculture Domain	[Conference Proceedings]	(Singh et al., 2019)
2018	6.94	Sentiment Analysis Through Tweets For "Doubling Farmers' Income" In India	Asian Journal of Science and Technology	(Hooda et al., 2018)
2018	N/A	A Framework for Sentiment Analysis Based Recommender System for Agriculture Using Deep Learning Approach	[Book chapter]	(Nimirthi et al., 2018)
2018	0.57	Sentiment analysis in social networks for agricultural pests	Advances in Intelligent Systems and Computing	(Bermeo-Almeida et al., 2018)
2018	0.57	Sentiment Analysis through Recent Tweets for "Agriculture" in India	Advances in Intelligent Systems and Computing	(Hooda and Hooda, 2018)
2018	N/A	Sentiment Analysis of Recent Tweets for Agriculture from BRICS Countries	[Thesis]	(Hooda, 2018)
2017	N/A	Predicting State-Level Agricultural Sentiment with Tweets from Farming Communities	[University Project]	(Dunnmon et al., 2017)
2013	N/A	A Framework for Opinion Mining in Blogs for Agriculture	Procedia Technology [Journal discontinued]	(Valsamidis et al., 2013)

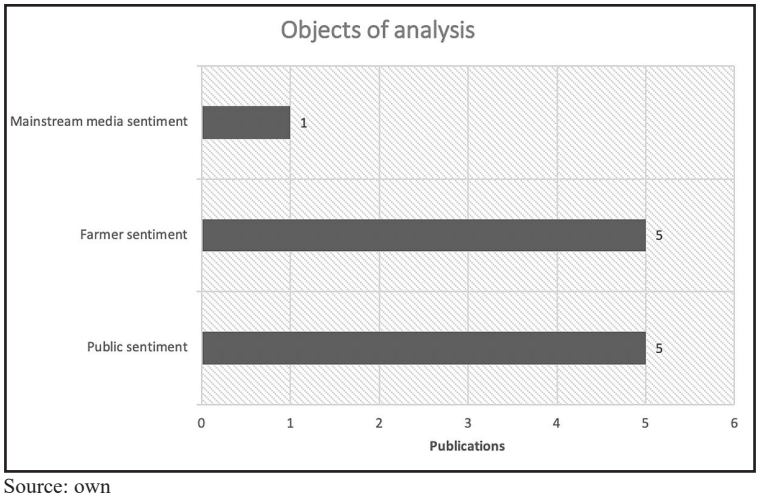
Source: own

Table 2: Result of literature discovery after application of requirements defined in Table 1.



Source: own

Figure 1: Publications related to sentiment analysis in agriculture per year.

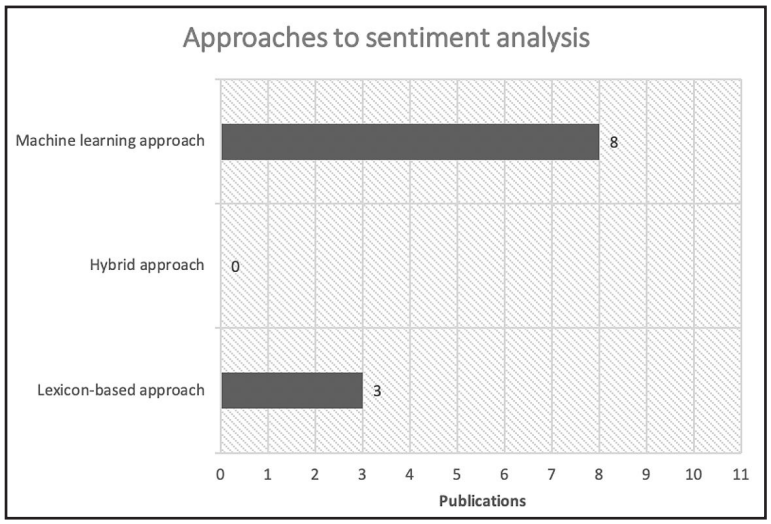


Source: own

Figure 2: Listing and occurrences of objects of analysis in the reviewed literature, based on input data source.

As shown in Figure 3, most of the research is evenly distributed between the first two of the fore-mentioned objects of analysis. The sentiment of mainstream media (more specifically headlines) is only analyzed in (Li et al., 2020). Nine out of eleven publications are working with input text in the English language, except for (Li et al., 2020), where the input text is Chinese and (Singh et al., 2019), where English is mixed with Punjabi dialect. The most commonly used algorithm for Sentiment analysis in agriculture is Naive Bayes, which also seems to be the most accurate algorithm used by researchers. Only four out of eleven researchers performed a model evaluation, therefore it is difficult to determine how accurate is Sentiment analysis in agriculture.

Although some of the reviewed research seems to be intended as a proof of concept for the application of Sentiment analysis in agriculture rather than to an application by itself (Valsamidis et al. 2013) (Nimirthi et al., 2018) (Bermeo-Almeida et al., 2018), there are also cases of research, where it has been integrated into complex prediction models (Li et al., 2020) (Dunnmon et al., 2017) or used as a powerful tool for assessment of public opinion on important topics, concerning the adoption of modern technologies and agrarian politics (Hooda et al., 2020)(Ofori and El-Gayar, 2020) (Salim et al., 2020). All authors of the reviewed literature seem to be convinced that Sentiment analysis has its use in agrarian research, but (Bermeo-Almeida et al., 2018) and (Dunnmon et al., 2017) point out that accuracy in ternary sentiment classification, which includes neutral sentiment is still significantly lower than in binary sentiment analysis, where only positive and negative sentiments are considered. For this reason, these two authors encourage further research to be focused on the improvement of accuracy in ternary sentiment classification. More detailed information available in Tables 3 to 13.



Source: own

Figure 3: Occurrences of approaches to sentiment analysis in methodologies of reviewed literature.

Input data	Posts from agriculture web blog ran by the authors
Input language	English
Pre-processing	Removal of symbols, URLs and emoticons + TF.IDF transformation
SA algorithm	Naive Bayes (binary classification)
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 3: Paper analysis – A Framework for Opinion Mining in Blogs for Agriculture.

Input data	Tweets referring to agriculture, location and weather
Input language	English
Pre-processing	Own built automatic pre-processor
SA algorithm	CNN, RNN (binary and ternary classification)
Model evaluation	Accuracy testing, IQR, Confusion matrix
Model accuracy	Up to 80 % for binary and up to 63 % for ternary

Source: own

Table 4: Paper analysis – Predicting State-Level Agricultural Sentiment with Tweets from Farming Communities.

Input data	Tweets referring to agriculture
Input language	English
Pre-processing	Removal of numbers, symbols, white spaces, URLs and emoticons
SA algorithm	Unspecified Lexicon-Based approach (NRC sentiment library in R)
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 5: Paper analysis – Sentiment Analysis of Recent Tweets for Agriculture from BRICS Countries.

Input data	Tweets referring to agriculture.
Input language	English
Pre-processing	Removal of numbers, symbols, white spaces, URLs and emoticons
SA algorithm	Unspecified Lexicon-Based approach (NRC sentiment library in R)
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 6: Paper analysis – Sentiment Analysis through Recent Tweets for "Agriculture" in India.

Input data	Tweets and Facebook posts referring to agricultural pests
Input language	English
Pre-processing	Removal of spec. characters, expansion of abbreviations, spellcheck
SA algorithm	Unspecified machine learning approach. (NLU software)
Model evaluation	Accuracy testing, Recall, F-Measure
Model accuracy	77.43 %

Source: own

Table 7: Paper analysis – Sentiment analysis in social networks for agricultural pests.

Input data	Tweets referring to agriculture
Input language	English
Pre-processing	Removal of numbers, symbols, white spaces, URLs and emoticons
SA algorithm	CNN
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 8: Paper analysis – A Framework for Sentiment Analysis Based Recommender System for Agriculture Using Deep Learning Approach.

Input data	Tweets referring to doubling income of farmers
Input language	English
Pre-processing	Removal of numbers, symbols, white spaces, URLs and emoticons
SA algorithm	Unspecified Lexicon-Based approach (NRC sentiment library in R)
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 9: Paper analysis – Sentiment Analysis Through Tweets For "Doubling Farmers' Income" In India.

Input data	Facebook, Twitter and Youtube Comments referring to agriculture
Input language	Mixed language (English and Punjabi)
Pre-processing	Removal of numbers, symbols, white spaces, URLs and emoticons
SA algorithm	SVM, Naive Bayes
Model evaluation	Accuracy testing
Model accuracy	85 %(SVM), 85.6 % (Naive Bayes)

Source: own

Table 10: Paper analysis – Sentiment Analysis of English-Punjabi Code-Mixed Social Media Content for Agriculture Domain.

Input data	Tweets referring to agriculture and smart farming
Input language	English
Pre-processing	Tokenization, Case folding, Stemming, Removal of stopwords
SA algorithm	Naive Bayes (binary classification)
Model evaluation	Accuracy testing, Confusion matrix, Recall, F1, AUC
Model accuracy	90 %

Source: own

Table 11: Paper analysis – Twitter Users Opinion Classification of Smart Farming in Indonesia.

Input data	Headlines of online news specialized in agricultural futures
Input language	Chinese
Pre-processing	None mentioned
SA algorithm	Bi-LTSM
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 12: Paper analysis – A novel text-based framework for forecasting agricultural futures using massive online news headlines.

Input data	Posts from Twitter, Reddit and other internet forums referring to PA
Input language	English
Pre-processing	None mentioned
SA algorithm	Unspecified machine learning approach (Buzz Monitor)
Model evaluation	None mentioned
Model accuracy	N/A

Source: own

Table 13: Paper analysis - Drivers and challenges of precision agriculture: a social media perspective.

Conclusion

The topic of Sentiment analysis in agriculture is not being researched very actively, which is obvious from the relative lack of literature compared to other fields of application of sentiment analysis. The topic has been slowly getting more attention since 2018 and the quantity of publications is rising fast since then.

The most common applications for Sentiment analysis in agriculture according to the reviewed literature are the determination of farmers' attitude towards events, policies and adoption of new technology, increasing the accuracy of prediction models by introducing sentiment-based variables and determining public attitude towards agriculture and its state in particular countries.

Machine learning approach to Sentiment analysis is dominating in the agrarian sector with the naive Bayes algorithm being the most commonly used method. Lexicon-based approaches are significantly less utilized and hybrid approaches have not been used at all.

On several occasions, the authors of the reviewed publications stated that more research should be directed to improving the accuracy of ternary sentiment analysis with the inclusion of neutral sentiment.

In summary, it has been proven that methods of Sentiment analysis have application in agriculture, and it would be a good idea to adopt them more widely especially for analyzing public opinion on topics related to the Agrarian sector. However, as shown by the reviewed literature, the methods of Sentiment analysis are most effective when enhancing or working in combination with other approaches, therefore it might be wise to focus future research on integrating Sentiment analysis into existing processes, rather than inventing stand-alone applications. Finally, it would be suitable to extend this research on applications of sentiment analysis in closely related fields, such as food quality and food production.

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Economic Consequences of Invasive Species in ornamental sector in Mediterranean Basin: An Application to Citrus Canker

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Abstract

Citrus Bacterial Cancer (CBC) is a severe phytopathy capable of compromising the economy, environment, and society in specific areas. To date, it is not present in the Mediterranean Basin. In essence, it could be a signal that European Phytosanitary Services have been able to control its spread, blocking import and marketing of fruits from risk areas or lacking the necessary phytosanitary requirements. However, in 2014 the EFSA launched the alarm on possible new forms of transmission of *Xcc* or *Xanthomonas citri*, the causative agent of the CBC, represented by the marketing of ornamental Rutaceae and the flow of tourism, to and from risk areas. In this context, the research carries aim to assess direct and indirect damages that an invasion of the CBC could cause to the sector: its impacts at the micro-economic level fall on the production system and the consumer, while at the macro level on the entire community. The traceability of plant material during commercial operations is proposed as a possible solution, even if it becomes an accessory burden for businesses and consumers. In this sense, this research intends to offer some useful information to public and private, interested parties and to plan intervention policies.

Keywords

Xanthomonas citri, ornamental rutaceae, economic impact, damage assessment with income method, nurseries industry.

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Introduction

Market globalization and climate change have increased the attention on the invasion of alien species and the spread of plant diseases, modifying the scenario of the defense of agricultural and forest plants. (Bradley et al., 2010; AA.VV., 2011; Chapman et al., 2017). The risks involve not only the agricultural, rural, forest, and landscape heritage but also biodiversity, ecosystem services, and public and private green areas (Timpanaro et al., 2014). The increasing costs deriving from current national emergencies, both in terms of direct damage to production and crops and in terms of expenses related to controls and eradication and containment measures, highlight the strategic role of defense and prevention that must be carried out by phytosanitary services, together with all the other international institutions interested in the plant protection. (European Food Safety Agency (EFSA); European and Mediterranean Plant Protection Organization (EPPO); EU Directorate General for Health and Food Safety (SANTE), the main body of the European Commission operating within the framework of the International Plant Protection Convention (IPPC), Food and Agricultural Organization (FAO) and under the agreements signed in the World Trade Organization (WTO); US Department of Agriculture Animal and Plant Health Inspection Service (APHIS) (Timpanaro et al., 2020).

Food and Agricultural Organization identified six types of direct and indirect economic impacts of invasive species (FAO, 2001; Ameden, 2007): production, price and market effects, trade, food security and nutrition, human health and the environment, and financial impacts.

There are many contributions in the literature on the different aspects of the invasion. These are some of them:

- Prevention and control (Horan et al., 2002; Finnoff and Shogren, 2004; Finnoff et al., 2007; Panetta and Gooden, 2017). In this case, the two main strategies

for the management of invasive species are mitigation (prevention with initiatives that aim to reduce the probability of an invasion occurring) and adaptation (control at any time during the invasion process and aim to reduce the extent of an attack rather than the likelihood of it happening) (Bellard et al., 2016);

- Application of rules and regulations (See and Dwight, 1984; Kambhu, 1990; Oh, 1995; Huang, 1996; Kadambe and Segerson, 1998; Genovesi et al., 2014). Researches show the optimal application of rules, the effect of taxation on company profits (Knowler and Barbier, 2005), the level of moral hazard of companies, which can pursue their interests at the expense of the community, trusting in the impossibility, for the latter, to verify the presence of willfulness or negligence (Shogren et al., 1990), costs of institutional monitoring. (Jenkins, 2002; Crowley et al., 2017);
- Effectiveness of different policy tools for invasive species, with the aim of trade regulation (Perrings, 2001; Costello and McAusland, 2003; McAusland and Costello, 2004; Horan and Lupi, 2005; Sheldon and Fitzpatrick, 2006). Potential policy instruments that may be used for prevention and control of invasive species including uniform technology standards, tradeable permits, fees and taxes as well as inspections. (Barbier et al., 2011; Jeschke et al., 2014);
- The ability to build an effective "bioeconomic modeling", capable of supporting political decisions. (Leung, 2002; Finnoff and Tschirhart, 2003; Shogren et al., 2006; Finnoff et al., 2006; Ameden et al., 2007; Finnoff and Tschirhart, 2003 and 2008), with an evolution from old approaches that provided for an intervention by the ex-post economist on the occurrence of the invasion to determine a "damage function" (Jardine and Sanchirico, 2018), to a modern ex-ante approach, according to which the economic system and ecosystem influence each other in preventing hypothetical damage from invasion.

In the latter case, the literature shows how the economic assessment of the impact of a hypothetical invasion is often demanding and inaccurate.

Economic impacts are classified into:

- primary (immediate impacts on affected farmers, with loss of income and economic and financial costs) and in secondary and tertiary (changes in consumer demand, relative prices of inputs, loss of biodiversity and other natural resources) (Evans, 2003);
- direct and indirect (Bigsby and Whyte, 2001), depending on whether the effects are due to the presence or dynamics of the alien species with effects on the community (such as the impairment of the main functions of the ecosystem; impacts on tourism and other sectors of the economy) or market (market access; consumer attitude towards a specific product; etc.).

Since international agreements on plant health and trade require that the assessment of the economic impact justify the regulation of a pest risk analysis (PRA), these are widespread in the literature. However, there are several qualitative assessments, which make the consequent regulatory decisions less effective, for example, whether or not to provide for a quarantine (Soliman et al., 2013; Anderson and Crosby, 2018; Bacher et al., 2018). Among the quantitative assessments, a comparative evaluation of the main techniques (partial budgeting, partial equilibrium analysis, input-output analysis, and computable general equilibrium analysis) is reported first by Born et al. (2005) and then in Soliman (2010). Then we must remember the empirical analyses carried out on citrus fruits in the USA due to the invasion of Huanglongbing (HLB), also known as Citrus Greening, capable of causing a reduction in production, in company profits, higher prices for consumers and a loss of jobs (Farnsworth et al., 2014; Moss et al., 2015); the quantification of direct damages over some time in which different types of invasions occurred in different territorial contexts (Williams et al., 2010; Andreu and Vilà, 2010; Hoffmann and Broadhurst, 2016; Atasoy and Çorbacı, 2018). Another perspective concerns the careful management of the limited financial resources available to support the impact of alien species, with a line of research that aims to identify the priority species also to guide the public reference regulation (legislation) (Courtois et al., 2018).

The last framework includes the intervention put in place to control bacterial citrus cancer (CBC), caused by two related but taxonomically distinct bacteria, named *Xanthomonas citri* pv. *citri* (synonym *X. citri* subsp. *citri*) and *X. citri*

pv. *aurantifolii* (synonym *X. fuscans* subsp. *aurantifolii*). The first, which is the Asian citrus cancer agent, is by far the most prevalent in the world. CBC causes significant economic damage caused by the loss or non-marketability of the fruit (Acquaye et al., 2005). The disease is present in some areas of North and South America, Africa, India, West Asia, China, East Asia but has never been reported in Europe and the Mediterranean basin. Therefore, the two responsible bacteria are included in the A1 List of quarantine pathogens of the European and Mediterranean Plant Protection Organization (EPPO) (Caruso et al., 2017). In this case, the containment measures put in place to counter the invasion of *Xcc* through citrus fruits, destined for food consumption have been effective. However, in recent years there has been growing concern, in consideration of the development of the citrus fruit market with ornamental function (Timpanaro et al., 2020).

For these reasons, the Panel on Plant Health (PLH) of the European Food Safety Authority (EFSA), in the document "Scientific Opinion on the risk to plant health of *Xanthomonas citri* pv. *Citri* and *Xanthomonas citri* pv. *Aurantifolii* for the EU territory" (EFSA 2014) identified, among possible ways of entry of the bacterium into the Mediterranean basin, trade flows of ornamental Rutaceae species, considering that some of these are widely cultivated in the Mediterranean countries and which activate an essential economic and social function due to the high number of nurseries involved. Another possible way of spreading *Xcc* is, again, according to EFSA, represented by the movement of passengers and the tourist flow. In a globalized world and with the scarcity of resources available to national phytosanitary services, controlling trade and tourist flows is not an easily achievable goal. The import of citrus fruits and other species of Rutaceae other than the traditional species traditionally marketed (e.g., lemon, kumquat, and squid) for ornamental purposes represents, for nursery workers, an opportunity to differentiate the commercial offer and grow the results of a company. Over time it has led to a growth of exchanges of non-traditional species, also increasing the potential risk of introduction and spread of *Xcc* and other alien pathogens in the EU and the Mediterranean basin. On the other hand, the risk associated with the introduction of emerging diseases has prompted the extension of the international marketing ban to an increasing number of ornamental Rutaceae with a consequent compromise of benefits for consumers and profits for nurseries (Directive 2000/29/EC and subsequent amendments).

The economic issue is not indifferent, because a hypothetical accidental invasion of the pathogen through ornamental Rutaceae could compromise citrus growing for food purposes, above all located in Spain, Italy, Greece, Portugal, Cyprus, France, and Malta.

The present work is part of this framework, created to carry out a first economic assessment of the possible damage caused by an invasion of CBC in the Mediterranean Basin, based on official statistical documentation and an estimate based on the detection of a concrete case in an area with a high vocation for the production of ornamental citrus fruits. The methodological approach was chosen according to the regional scale and the availability of data and allowed to estimate the change in the profitability of companies, to meet a specific need expressed by different public and private stakeholders and to design a particular intervention program and policies.

Materials and methods

In order to extrapolate the areas invested in ornamental citrus fruits in the Mediterranean Basin, it was necessary to always use the EUROSTAT source and, in particular, to the "EUROSTAT Handbook for Anniversary Crop Statistics" (Regulation (EC), No. 543/2009, Commission Delegates Regulation (EU) 2015/1557 and ESS Agreement for the Annual Crop Statistics (Revision 2017).

Within the latter it was necessary to analyze the "FFS number", go back to "New Code", to the "Aggregate name" to the "Latin name and definition" and to the "Notes and explanation", to extrapolate the data of the most ornamental citrus fruits in cultivation.

The results of this discriminant analysis, although aware of its incompleteness, includes the following ornamental Rutaceae, species and varieties:

LABEL	RUTACEOUS INCLUDED
Other small citrus fruits (including hybrids) n.e.c.	*Murraya paniculata, Koenigiu, exotica, Microcitrus australasica; Severinia buxifolia; Poncirus trifoliata*
Other citrus fruits n.e.c.	*Citrus bergamia, C. Myrtifolia, C. Hystrix, C. Fortunella crassifolia, hindsii, japonica, margarita, abovata; Limonia acidissima; Lunasia (L. amara)*
Lemons and acid limes	*Limone meyer, Limetta romana, Limetta mexicana*
Satsumas	*Citrus Unshiu,* var. *owari*

To assess the potential production of ornamental Rutaceae, starting from the statistical universe represented by the whole compared to "ornamental flowers and plants" in the EU, we used the EUROPHYT database. It is established and managed by the Directorate-General for Health and Food Safety of the European Commission, which deals with the interception for plant health reasons for parts of plants and plant products imported or distributed into the EU. EUROPHYT brings together all the results of the activity carried out by the various national phytosanitary services within a database, containing interceptions, trade within a non-EU plant species to provide essential support for the criteria of preventive measures. The main advantage of this source is that the data on the health risks of plants, deriving from the trade of plants and plant products carried out by professional operators, are updated and accurate. At the same time, the source has the limitation of not containing complete information relating to a possible introduction into the EU of harmful organisms through the commercial activity by non-professional operators (who enjoy specific derogations) or passengers - aware or unaware - of being vectors of alien species.

Assessed - with the limits just mentioned - the size of the sector in the territory, we proceeded with the evaluation of the production cost of the ornamental citrus seedling, to provide an economic evaluation based on the "producer price" (how to determine the income based on the "distribution" between the different figures of earners).

This assessment was carried out in Sicily, an area with the elective conditions, over the last twenty years, for the production of the ornamental citrus fruit. The commercial interest has arisen concerning the fact that most of the species of the genus Citrus and similar, have specific morphological and productive characteristics particularly responsive to the ornamental use, (for example the non-transience - winter of the leaves and the re-flowering). These products are increasingly destined to the amateur level in the gardens, in real gardens up to the city apartments.

For the determination of production costs, 10 nurseries were detected in Sicily, in particular, located between Catania (30%), Messina (60%) and Trapani (10%) in coastal areas (Basile et al., 2000). The cost refers to a lemon seedling, with a degree of preparation at 36 months; the data were collected in 2018 and, in some cases, related to the last three years (2016-2018) and were elaborated with the following model widely used at European level:

$$Ep=[(FNVA+S)-(T+W+R+F+L+C)]$$

where:

Ep = Economic profit; *FNVA* = Farm Net Value Added; *S* = subsidies on investment; *T* = Taxes on investment; *W* = Wages and social security charges; *R* = Rent paid for farm land and buildings and rental charges; *F* = Family labor costs; *L* = Costs of own land costs; *C* = Costs of own capital costs.

The decision to focus on this species and on the 36-month staging was due to some reasons related to:

1. a typical Mediterranean citrus cultivation - the lemon - which boasts a history for ornamental purposes in pot that transcends the local and national context (in Tuscany, around 1960 began the trade of the lemon in pot that gave rise to the sector);
2. a considerable liveliness of the sector, with continuous and increasing adaptations in the product configuration;
3. an inflow of technological innovations of product and process in the production units, characterized by high levels of improvement of the activities;
4. competitive strategies of companies and business opportunities offered by a constantly evolving market, where production costs and availability to the consumer are the fundamental determinants of the company.

In this scenario, various problems emerge regarding:

- company organizational structure, as a result of the application of various management techniques and methods;
- use of common resources and more products, not only citrus but also on other species such as olive, laurel, etc.;
- obtaining a multitude of commercial products.

In the first and the second case, the companies were categorized into well-differentiated operative units designed to host ornamental plants in pots at different levels of development. The production

process, related to each line (production cycle), takes place in a sequence of functional environments in space and time, different for the structures and productive means used, coherent with each phase of development of the pot plants.

In the third case - although found in the companies surveyed, a multitude of production lines concerning specific mercantile choices (which tend to extend the duration of the production process to more than 3 years) - it was decided to refer to the final layout in 21 cm diameter vase. In fact, from the investigations, the following articulation of the production lines emerged, as a result of which this choice was made:

Size	%
Soilcells	5-10%
16-18 cm pot	5-10%
20-22 cm pot	30-40%
24-25 cm pot	20-30%
26-28 cm pot	20-25%
35 cm pot	0-5%

Results and discussion

1. Scenario on the European ornamental plants and flowers sector

The economic assessment of the impact of *Xcc* on ornamental citrus production is challenging to determine due to the shortcomings in the availability of official statistics divided by species, variety, and economic destination (commercial or ornamental).

The international data available are often referred to as the aggregate "ornamental flowers and plants," with or without the inclusion of "Christmas trees." Furthermore, since they are productions usually made by nurseries, some determinations lose significance, as we do not find strictly specialized structures in a single species or variety (Foti et al., 2017).

In Europe, the sector is widely diffused and decreasing in terms of production units (-25%), as shown in Table 1. In 2013 (data made available in 2018), a total of 10.8 million companies are active in the production of flowers and ornamental plants.

The only country bucking the trend is Ireland (+ 5%), while the traditional producing countries show evident contractions (Italy, -42%, Holland, -18%, France, -17%, Spain, -11%, etc.).

The restructuring process of the sector took place with a different trend in investments, which in the same period reached 220 thousand hectares, an increase of 20% (Table 2).

The restructuring process took place differently in different countries, with a consequent widening of the average size. Therefore, investments in Italy and Spain are expanding, recording respectively +463% and +57%, in Portugal (+28%), in the Netherlands (+19%), in Poland (+47%), etc. The contraction, however, has affected, to a lesser extent France (-8%) and, to a greater extent Greece (-5%). Furthermore, all countries present a different production specialization, with the varying incidence of "outdoor" and "under glass" cultivation, as shown in Figure 1.

Area	2005 n.	2007 n.	2010 n.	2013 n.	Index
Belgium	51,540	48,010	42,850	37,760	**73**
Bulgaria	534,610	493,130	370,490	254,410	**48**
Czech Republic	42,250	39,400	22,860	26,250	**62**
Denmark	51,680	44,620	41,360	38,280	**74**
Germany	389,880	370,480	299,130	285,030	**73**
Estonia	27,750	23,340	19,610	19,190	**69**
Ireland	132,670	128,240	139,890	139,600	**105**
Greece	833,590	860,150	723,060	709,500	**85**
Spain	1,079,420	1,043,910	989,800	965,000	**89**
France	567,140	527,350	516,100	472,210	**83**
Croatia	:	181,250	233,280	157,440	**87**
Italy	1,728,530	1,679,440	1,620,880	1,010,330	**58**
Cyprus	45,170	40,120	38,860	35,380	**78**

Source: EUROSTAT

Table 1. Flowers and ornamental plants: total number of farms and areas in Europe (to be continued).

Area	2005 n.	2007 n.	2010 n.	2013 n.	Index
Latvia	128,670	107,750	83,390	81,800	**64**
Lithuania	252,950	230,270	199,910	171,800	**68**
Luxembourg	2,450	2,300	2,200	2,080	**85**
Hungary	714,790	626,320	576,810	491,330	**69**
Malta	11,070	11,020	12,530	9,360	**85**
Netherlands	81,830	76,740	72,320	67,480	**82**
Austria	170,640	165,420	150,170	140,430	**82**
Poland	2,476,470	2,390,960	1,506,620	1,429,010	**58**
Portugal	323,920	275,080	305,270	264,420	**82**
Romania	4,256,150	3,931,350	3,859,040	3,629,660	**85**
Slovenia	77,170	75,340	74,650	72,380	**94**
Slovakia	68,490	68,990	24,460	23,570	**34**
Finland	70,620	68,230	63,870	54,400	**77**
Sweden	75,810	72,610	71,090	67,150	**89**
United Kingdom	286,750	226,660	185,200	183,700	**64**
Iceland	:	:	2,590	:	
Norway	53,000	49,940	46,620	43,730	**83**
Switzerland	63,630	61,760	59,070	:	**93**
Montenegro	:	:	48,870	:	
Total	**14,598,640**	**13,920,180**	**12,402,850**	**10,882,680**	**75**

Source: EUROSTAT

Table 1. Flowers and ornamental plants: total number of farms and areas in Europe (continuation).

Member state	2007			2010			2013			2016			**Index**
	nursery	other	total	nursery	other	total	nursery	other	total	nursery	Other	total	
Germany	20.9	7	27.9	20.9	8.4	29.3	20.7	7.7	28.4	19.3	7.3	26.6	**95**
Spain	15.6	3	18.6	19.2	6.7	25.9	20	7	27	22.8	6.4	29.2	**157**
Netherlands	14.9	27.5	42.4	17.4	26.2	43.6	17.5	26.2	43.7	17.8	32.6	50.4	**119**
France	18.3	7.9	26.2	18.3	8.1	26.4	15	9	24	15.1	8.9	24	**92**
Poland	11.7	2.7	14.4	0	3.8	3.8	11.8	3.4	15.2	16.3	4.9	21.2	**147**
Hungary	10.6	0.4	11	11.4	0.5	11.9	7.5	0.5	8	6.3	0.5	6.8	**62**
United Kingdom	7	6	13	6	5	11	6	6	12	6	6	12	**92**
Bulgaria	0	3.6	3.6	2.1	0	2.1	1.9	0	1.9	2.2	0	2.2	**61**
Czech Republic	0	1.9	1.9	0.4	1.3	1.7	1.7	0.3	2	2.2	0.3	2.5	**132**
Austria	2.5	0.2	2.7	2	0.4	2.4	1.8	0.4	2.2	2.3	0.4	2.7	**100**
Greece	1.5	0.5	2	1.5	0.5	2	0.6	0.5	1.1	0.7	0	0.7	**35**
Belgium	4.7	1	5.7	1.5	5	6.5	1.2	5.2	6.4	1.3	5.3	6.6	**116**
Portugal	1.1	1.8	2.9	1	2.1	3.1	0.3	2.9	3.2	0.2	3.5	3.7	**128**
Lithuania	0.2	0.1	0.3	0.4	0.1	0.5	0.4	0.1	0.5	0.4	0.2	0.6	**200**
Slovenia	0.2	0.2	0.4	0.4	0.1	0.5	0.3	0.1	0.4	0.3	0.1	0.4	**100**
Slovakia	0	0.3	0.3	0.4	0.2	0.6	0.3	0.2	0.5	0.4	0.1	0.5	**167**
Croatia	0.2	0.1	0.3	0.4	0.3	0.7	0.2	0.3	0.5	0.3	0.3	0.6	**200**
Romania	0.7	0.3	1	0.8	0.2	1	0.5	0.5	1	0.3	0.5	0.8	**80**
Luxembourg	0.1	0	0.1	0.1	0	0.1	0.1	0	0.1	0.1	0	0.1	**100**

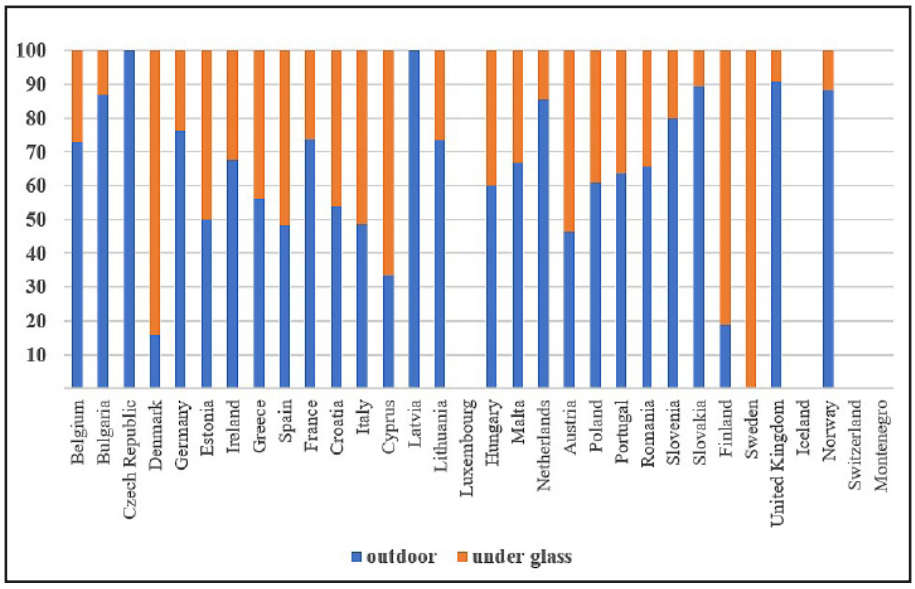
Source: EUROSTAT and DGAGRI-G2, Working Document on Flowers and Ornamental Plants, Statistics 2006-2016

Table 2: Flowers and ornamental plants: 1,000 hectares and areas in Europe (to be continued).

Member state	2007			2010			2013			2016			Index
	nursery	other	total	nursery	other	total	nursery	other	total	nursery	Other	total	
Malta	0	0	0	0	0.1	0.1	0	0	0	0	0	0	-
Denmark	0	2.3	2.3	0	1.9	1.9	1.2	0.3	1.5	2	0.3	2.3	**100**
Estonia	0.4	0.1	0.5	0.5	0	0.5	0.2	0	0.2	0.2	0	0.2	**40**
Ireland	0	0	0	0.2	0.1	0.3	0.3	0.2	0.5	0.3	0.2	0.5	-
Italy	0	4.3	4.3	0	0	0	0	0	0	24.2	0	24.2	**563**
Cyprus	0.1	0.2	0.3	0.1	0.1	0.2	0	0.2	0.2	0	0.1	0.1	**33**
Latvia	0	0.1	0.1	0	0.1	0.1	0	0.1	0.1	0.3	0.1	0.4	**400**
Finland	0	0	0	0	0	0	0	0	0	0	0	0	-
Sweden	0.4	0.5	0.9	0.4	0.4	0.8	1.8	0.2	2	0.5	0.2	0.7	**78**
Total	**111.1**	**72**	**183.1**	**105.4**	**71.6**	**177**	**111.3**	**71.3**	**182.6**	**141.8**	**78.2**	**220**	**120**

Source: EUROSTAT and DGAGRI-G2, Working Document on Flowers and Ornamental Plants, Statistics 2006-2016

Table 2: Flowers and ornamental plants: 1,000 hectares and areas in Europe (continuation).



Source: EUROSTAT

Figure 1: Distinction of flower and ornamental plant in Europe by production method.

In general, at higher latitudes, in the countries of Northern Europe, there is an increase in the rate of cultivation "under glass," to preserve the characteristics of the value, especially in the production of flowers (Timpanaro et al., 2013; Butti Al Shamsi et al., 2018).

For this reason, it was necessary to adopt a specific discriminant analysis for customs tariff codes, starting from the same EUROSTAT statistics, to evaluate the most probable economic value of the impact of *Xcc*.

A picture of the production generated by the aggregate "ornamental plants and flowers (including the Christmas tree)" is visible in Table 3, which highlights the evolution of the output of the sector in the last decade.

From these data emerges a fluctuating trend in the sector over the entire period analyzed and the role of "key actors" in some countries. In fact, in the EU - in its "current composition" - the sector realizes production of 8,060 million euros, in which contribute in order of importance Netherlands (with 30% of this value), Germany and Italy (14% each), France (12%), Spain (about 9%), Denmark (about 5%) and Switzerland (about 4%).

In these evaluations, a significant role is played by "flowers" as traditional production in specific territories.

Area	2008	2009	2010	2011	2012	2013	2014	2015	2016
European Union (current composition)	9,238.52	8,663.15	9,519.14	9,099.24	8,762.64	8,628.44	8,339.91	7,970.99	8,059.58
European Union (before the accession of Croatia)	9,097.41	8,527.07	9,392.79	8,986.58	8,684.64	8,562.63	8,274.59	7,912.70	8,000.07
European Union (25 countries)	9,042.31	8,486.12	9,337.90	8,916.28	8,554.74	8,437.02	8,197.95	7,866.81	7,939.54
European Union (15 countries)	8,690.58	8,203.77	9,002.75	8,525.92	8,166.14	8,075.09	7,900.08	7,557.89	7,634.92
Euro area (19 countries)	8,218.55	7,732.08	8,507.72	7,994.78	7,632.46	7,555.70	7,419.66	7,078.00	7,169.46
Euro area (16 countries)	8,209.88	7,726.62	8,504.10	7,991.34	7,628.85	7,551.76	7,415.65	7,069.40	7,162.58
Euro area (12 countries)	8,175.68	7,693.68	8,470.33	7,956.52	7,594.49	7,519.61	7,388.06	7,041.11	7,134.68
Euro area (11 countries)	8,039.40	7,589.56	8,387.82	7,878.71	7,528.20	7,459.27	7,332.65	6,988.61	7,082.29
Belgium	254.18	247.30	241.96	227.06	226.58	199.83	199.51	193.44	185.71
Bulgaria	0.07	0.22	0.53	0.51	2.64	3.57	4.12	2.16	7.58
Czech Republic	112.26	109.61	119.57	127.22	128.53	119.21	107.20	96.78	105.07
Denmark	407,62	403.29	413.29	435.46	417.36	410.18	374.02	377.54	358.95
Germany	1,505.00	1,412.00	1,825.98	1,757.07	1,361.28	1,310.41	1,142.93	1,111.63	1,133.03
Estonia	5.09	3.45	2.19	1.98	2.09	2.49	2.49	6.92	5.07
Ireland	29.93	28.96	27.67	28.18	25.25	26.64	28.16	31.04	33.30
Greece	136.28	104.12	82.51	77.81	66.29	60.34	55.41	52.50	52.39
Spain	870.76	995.19	1,190.61	877.46	851.56	944.84	1,037.32	724.21	697.83
France	924.20	953.90	932.90	953.50	981.40	997.30	966.40	967.40	1,004.10
Croatia	141.11	136.08	126.35	112.66	78.00	65.80	65.32	58.29	59.50
Italy	1,641.44	1,467.14	1,455.71	1,386.15	1,330.25	1,224.18	1,202.44	1,145.74	1,124.59
Cyprus	15.34	14.12	14.63	15.97	15.71	13.74	9.51	9.31	8.75
Latvia	3.58	2.01	1.42	1.47	1.52	1.44	1.51	1.67	1.81
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.75	2.29	0.40	0.37	0.41	0.36	0.62	0.59	0.71
Hungary	40.91	33.02	47.27	55.05	41.67	39.14	32.53	33.53	31.75
Malta	0.00	0.00	0.00	0.00	0,00	0.00	0.00	0.00	0.00
Netherlands	2,332.18	2,015.59	2,246.29	2,188.05	2,273.24	2,310.02	2,323.23	2,354.00	2,419.72
Austria	177.61	184.43	183.94	182.24	177.62	165.07	177.08	182.37	197.39
Poland	155.70	101.31	130.91	169.84	180.44	167.48	126.55	141.73	133.02
Portugal	197.45	176.27	182.95	194.98	186.70	193.26	168.13	192.22	194.74
Romania	55.03	40.73	54.36	69.79	127.26	122.05	72.51	43.73	52.95
Slovenia	4.45	3.88	4.04	3.74	3.54	3.30	2.97	3.87	4.05
Slovakia	14.40	14.94	15.11	15.11	15.11	15.11	15.11	15.11	15.11
Finland	105.90	106.50	99.40	83.65	113.92	87.37	86.83	85.98	91.17
Sweden	107.28	106.81	119.14	133.93	154.29	145.31	137.99	139.24	141.29
United Kingdom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	3.95	3.25	3.77	3.76	3.48	4.23	4.68	4.65	7.37
Norway	26.57	25.76	29.31	30.81	31.87	29.88	27.77	25.65	24.68
Switzerland	251.70	262.48	279.09	303.33	336.11	290.28	314.80	328.59	300.76
Former Yugoslav Republic of Macedonia	0.00	0.00	:	:	:	:	:	:	:

Source: EUROSTAT, Bruxelles (2018).

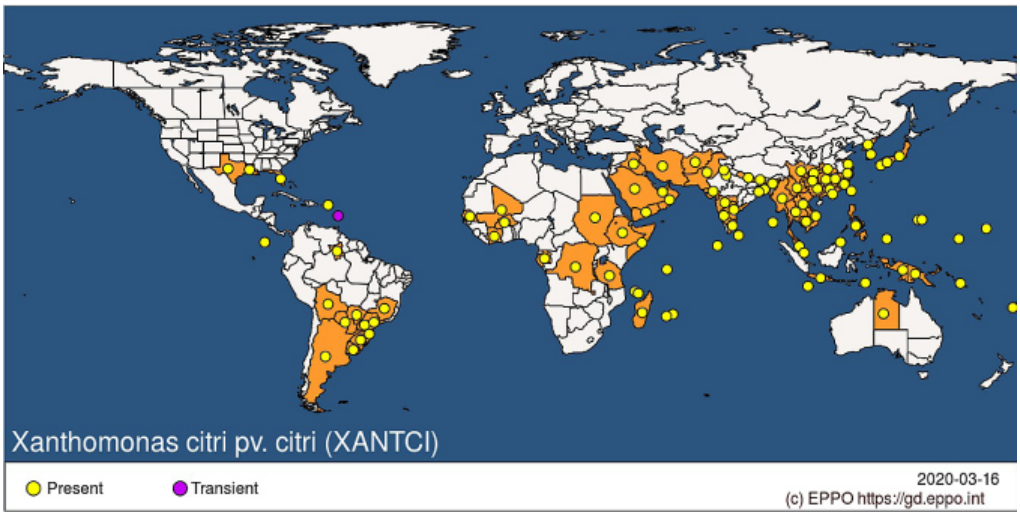
Table 3. Economic accounts for “Ornamental plants and flowers (including Christmas trees)” - values at current prices (Production value at producer price) (Mln EURO).

2. The spread of *Xcc* in the world and possible implications for ornamental Rutaceae in the Mediterranean Basin

EPPO has signaled the presence of *Xcc* in Asia, Africa, America, and recently in Oceania (Western Australia; Fiji; Guam; Marshall Islands; Micronesia), although with diversified importance in the various environments (Figure 2). In the various environments, Xcc is present in a diversified way (Present, no details; Present, widespread; Present, restricted distribution; Present, few occurrences), transient (Transient, under eradication) or absent (Absent, confirmed by survey; Absent, invalid record; Absent, pest eradicated).

The annexes of Directive 2000/29/EC (and subsequent amendments and additions) have been modified over time to include some random agents of CBC to protect the Mediterranean Basin. In particular, the directive intervenes in the prevention of many species of the genus Citrus, Fortunella, Poncirus, Murraya könig (in fact, since subject to Diasphorina citri Kuway) and related hybrids (subject to contamination), except fruits and seeds.

According to EUROPHYT, interceptions in over 73% of cases concern some countries, such as Bangladesh, Pakistan, China, India, Vietnam and Uruguay and, in particular, some species of ornamental Rutaceae (Citrus aurantifolia, Citrus latifolia, Citrus limon, Citrus hystrix, and Citrus SPP) and the mainly involve propagation material (scions and cuttings), often without the necessary plant passport (Table 4).



Source: EPPO Global Database, 2020

Figure 2: Spread of *Xcc* worldwide (EPPO, 2020).

	Citrus aurantifolia	Citrus latifolia	Citrus limon	Citrus limettoides	Citrus paradisi	Citrus reticulata	Citrus Maxima	Citrus hystrix	Citrus sinensis	Citrus amblycarpa	Citroncirus	Citrus SP.	Non-citrus species	Total
Bangladesh	11	9	4	-	-	-	-	-	1	-	-	14	3	42
Pakistan	3	10	-	1	1	4	-	-	-	-	-	4	1	24
China	-	-	-	-	2	-	14	-	-	-	-	-	-	16
India	4	-	4	-	-	-	-	-	-	-	-	3	2	13
Vietnam	-	4	-	-	-	-	-	5	-	-	-	1	-	10
Uruguay	-	-	6	-	-	1	-	-	5	-	-	-	-	12
Thailand	-	-	-	-	-	-	-	2	-	-	-	4	1	7
Argentina	-	-	6	-	-	1	-	-	2	-	-	-	-	9
Malaysia	-	1	-	-	-	-	-	2	-	-	-	3	-	6
Indonesia	-	-	1	-	-	-	-	6	-	1	-	-	-	8
Bolivia	-	-	4	-	-	-	-	-	-	-	-	-	-	4
Brazil	-	5	-	-	-	-	-	-	-	-	-	-	-	5
United Arab Emirates	-	-	-	-	-	1	-	-	-	-	-	-	1	2
Others											3			3
														161

Source: Our elaboration on Euphidra data.

Table 4: Interceptions of *Xcc* by country and species (2019).

The process of extrapolation of the data on ornamental citrus fruits has revealed a spread in the Mediterranean basin of more than 4.4 thousand hectares invested in these Rutaceae and an intense polarization in some countries (Italy, France, Spain, Turkey, and Greece) (Table 5).

This assessment is based on the areas subject to the phytosanitary provisions in force in the EU since 14 December 2019 (EUROPHYT), mainly derived from professional nurserymen, i.e., operators who, according to the current regulation (EU) 2016/2031, are legally responsible for one or more operations from the plant, reproduction, production, including cultivation, multiplication and maintenance, introduction, movement within the Union territory and out of the Union territory, made available on the market; storage, collection, shipping, and processing. They must also register with an Official Register of Professional Operators (RUOP) and guarantee an effective traceability system.

In reality, the production potential of ornamental Rutaceae is higher if we also consider the large amount of propagation material that ends up in the circuit of non-professional Operators or home gardeners, in travelers' luggage or the event that the movement of plants or parts of plants it is directly addressed to an end-user. In essence, anyone can purchase the product on electronic sites or other means of sales through distance contracts, for which the same EU Reg. 2016/2031 maintains specific exemptions (articles 75; 81).

The world of non-professional operators is very large and varied (retail bedding and nursery stock; greenhouse/annuals; retail lawn and garden products; retail general merchandise; retail landscape materials; nursery container and field; landscape services/build; landscape architecture/ design; wholesale bedding and nursery stock; retail garden equipment; wholesale landscape materials; retail florist and florist supplies; retail food and beverage; lawn and garden equipment; wholesale lawn and garden products; wholesale florist and florist supplies; wholesale garden equipment), and so is that of electronic commerce (multi-channel, electronic, and direct distribution for final consumption, EU Reg. 2017/625 identifies two elements as a defense against invasion or the traceability and control of the supply chain in a physical location. However, the consumer can connect directly to platforms, not of production but of intermediation, which offers products of all kinds, also of evident foreign, community,

Country	Other small citrus fruits (including hybrids) n.e.c. (a)	Other citrus fruits n.e.c. (b)	Lemons and acid limes (c)	Satsumas (d)	Our evaluationtotal (% a+b+c+d)
Greece	0.00	0.93	3.26	0.00	**0.177**
Spain	28.87	1.09	43.08	8.49	**0.821**
France	0.38	0.00	0.94	0.00	**0.782**
Croatia	2.10	0.00	0.06	0.00	**0.048**
Italy	0.00	1.55	25.61	0.00	**1.436**
Cyprus	1.06	0.04	0.47	0.00	**0.056**
Malta	0.00	0.00	0.00	0.00	**0.00**
Portugal	1.49	0.00	1.00	0.17	**0.266**
Total (a)	*33.90*	*3.61*	*74.42*	*8.66*	***3.586***
EU (28 Country) (b)	*42.47*	*3.67*	*74.91*	*8.66*	***4.579***
*(a) / (b) * 100*	*79.8*	*98.4*	*99.3*	*100.0*	***78.3***
Montenegro	0.15	0.00	0.00	0.00	**0.015**
Albania	0.00	0.00	0.05	0.01	**0.006**
Bosnia and Herzegovina	0.00	0.00	0.00	0.00	**0.000**
Turkey	23.00	0.01	32.00	24.00	**0.791**
Total (c)	*23.15*	*0.01*	*32.05*	*24.01*	***0.812***
Total (a) / (c)	*57.05*	*3.62*	*106.47*	*32.67*	***4.398***

Source: EUROSTAT and our elaborations for the extrapolation of the ornamental citrus data from the total item relating to the citrus genus

Table 5. Estimation of the area invested in ornamental citrus fruits in the EU, with particular reference to some countries of the Mediterranean Basin 2018 (1,000 ha).

or non-EU origin). According to EU Reg. 2019/2072, these end-users should report if they find the presence of *Xcc* since the latter is included in the list of quarantine pests relevant for the Union, in particular in "Part A - Harmful organisms the existence of which is not known in the territory of the Union".

3. Economic assessment of the damage from *Xcc* invasion

Direct costs determination at the micro-level

Based on the indicated methodology, we extrapolated a determination of the standard production costs of an ornamental Rutaceae seedling in a representative area (Allegra and Zarbà, 2015).

Overall, an average production cost of 4.528 Euro/seedling of *Citrus limon lunario* emerged on *Citrus wolkameriana*, to which the materials (35%) the works and services (about 40%) and the quotas and the other contributors in a different way attribution (about 28%), as shown in Table 6.

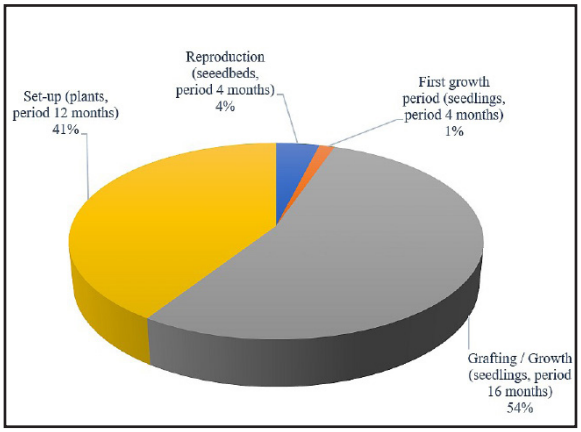
Indication	EURO/plant	%
Matherials	**1.466**	**32.40**
- propagation matherials	0.037	0.83
- single-use pots	0.043	0.96
- pots for sale	0.492	10.87
- soil	0.171	3.77
- plant-protection products	0.149	3.30
- fertlizers	0.262	5.78
- other products	0.312	6.89
Labour and services	**1.806**	**39.90**
- abour	1.608	35.51
- phytosanitary treatments	0.159	3.52
- internal handlings	0.038	0.85
Other costs	**1.256**	**27.70**
- fees	0.363	8.01
- department manager	0.121	2.67
- irrigation equipment	0.073	1.60
- warehouses for machines and tools	0.052	1.14
- screen house	0.212	4.68
- capital interests	0.101	2.23
- advance rate (1%)	0.042	0.92
- salaries	0.121	2.67
- taxes	0.030	0.66
- transactional costs	0.022	0.49
- direction	0.121	2.67
Total costs per plant	**4.528**	**100.00**

Source: Our elaboration on data results from direct survey

Table 6: Average unit production cost of an ornamental lemon plant in Sicily (2018).

The average uses of production factors (rootstocks and marzas for varieties, pots, etc.) influence the cost of materials. The use in each department weighs heavily on the job cost, especially in grafting operations. Lastly, the costs of management, administration and surveillance and the management of the "screen house" intercept the highest rates ("screen house" is the structure for the production of certified cuttings used in the constitution of the grafts of the Lunario cultivars. the regional phytosanitary services also control it).

The composition of costs during production (36 months), shows (Figure 3) the weight of reproduction operations (4%) and nest/growth (54%), compared to the set-up activity (12 months) of plants (41%). These data lead some nurserymen to acquire outside the seedlings directly by other nurserymen traditionally active in the regional, extra-regional, and overseas flower-growing areas. This practice generates some safety about the spread of Xcc since, in the standard, these structures are activated with official recognition phytosanitary authorities competent in the matter.



Source: Our elaboration on data results from direct survey

Figure 3: Structure of the average production cost of an ornamental citrus plant in Sicily by vegetative phase (36 months).

For the construction of a scenario of a possible economic impact of *Xcc* in the Mediterranean basin, it was necessary to integrate the official statistics using the FAO data in addition to the EUROSTAT data (Table 7).

In this case, the data are no longer referred only to ornamental citrus fruit but to the entire "citrus" genus, to have a clear - though apocalyptic - scenario of invasion and infection extended to the whole of commercial citrus production.

Countries	2016		2014
	ha	t	EUR
Albania	1,547.00	41,051.00	9,437,580.78
Algeria	58,663.00	1,201,847.00	930,489,084.36
Bosnia and Herzegovina	281.00	210.00	0.01
Croatia	2,192.00	53,257.00	14,724,781.93
Cyprus	2,166.00	79,047.00	16,586,384.79
Egypt	196,273.00	4,806,393.00	849,776,201.81
France	4,339.00	51,869.00	10,970,264.05
Greece	54,450.00	1,099,642.00	268,297,445.92
Israel	17,529.00	318,000.00	201,559,926.88
Italy	146,691.00	2,561,555.00	1,599,059,659.38
Jordan	5,976.00	115,536.00	33,177,592.77
Lebanon	12,355.00	299,750.00	121,701,784.71
Libya	8,009.00	81,263.00	17,187,078.36
Malta	126.00	1,730.00	1.20
Montenegro	1,099.00	12,818.00	2,710,999.72
Morocco	123,112.00	2,042,273.00	533,027,952.66
Occupied Palestinian Territory	1,208.00	20,441.00	371,398.48
Portugal	20,336.00	354,065.00	107,802,589.78
Réunion	112.00	1,844.00	390,004.95
Spain	361,477.00	6,950,952.00	1,220,938,644.42
Syrian Arab Republic	44,748.00	1,204,286.00	254,705,805.19
Tunisia	35,279.00	377,086.00	64,596,925.01
Turkey	129,488.00	4,039,887.00	288,714,062.55
Total	**1,227,456.00**	**25,714,802.00**	**6,546,226,169.74**

Source: Food and Agriculture Organization of the United Nations (FAO)

Table 7: Some indicators on citrus fruits in the countries of the Mediterranean Basin (2018).

Economic dimension of Rutaceae production in the Mediterranean Basin

What emerges is the importance of the citrus genus for this area in which - even if differentiated by country - it amounts to over 1.227 million hectares and almost 26 million tons, with a production of over 6.5 billion euros.

Table 7 shows the weight of each country and, in particular, Italy (almost 1.6 billion euros), Spain (over 1.2 billion euros), France (about 11 million euros), and Turkey (288 billion euros).

For the determination of the economic impact of *Xcc*, it was then proceeded by retrieving in literature the possible damages caused by a possible infection and defining some hypotheses concerning, for example, a possible protection protocol.

To this end, we have to consider that the spread of Xcc can - according to a pessimistic approach - have a macroeconomic impact on the entire sector, putting at risk the estimated production value for ornamental citrus and in the most extreme cases the value of the industry of commercial citrus fruits, with considerable economic impact (Table 8).

Products	Source	Value Mln €
Ornamental citrus	Our assessment	2,424.35
Commercial citrus	FAO	6,546.23

Source: Our assessment and FAO

Table 8: Production of ornamental and commercial citrus fruits in the Mediterranean basin potentially threatened by the invasion of *Xcc* (2018).

At the microeconomic level (nursery farm), on the other hand, we proceeded with an income approach. It is a generalization that is linked to scenarios of hypothetical lower profitability obtainable from the sector as a consequence of the advent of *Xc*c and that in no way does not take into account indirect impacts (induced), social

costs (supported by the system that should be called upon to deal with a phytosanitary problem) and the reduced possibility of use and recreation by the consumer that is difficult to determine in the absence of systematic data.

To that end, in Sicily, according to the data of the Regional Councilor for Agricultural and Food Resources, it is possible to hypothesis within the nurseries a density varying between 45 thousand and 60 thousand plants/hectare. Not only that, but the survey conducted in Sicily has allowed highlighting the endogenous characteristics of the main types of companies with ornamental citrus nursery, and the entrepreneurial approach eventually followed (different between micro-very small and medium-large nursery). The reactions of nurseries to Xcc can be very different, from total indifference to extremely particular forms of prevention (Scuderi and Sturiale, 2016). Therefore, we analyzed two company balances (referring to 2018), so it is possible to quantify the probable damage in:

1. Lack of income, resulting in irreversible damage for loss of plants;
2. Increase in production costs as a result of adopting more frequent prevention techniques (for example defined in a sort of guidelines, which include defense, control, surveillance, removal of plant parts, etc.).

The first analysis is based on the income approach. It provides for the determination of the capitalization or yield rate necessary to update the income that the ornamental citrus plant can provide. This test considering alternative investments, however similar, for security and economic duration was calculated by mediating the yield of long-term government securities for the year 2018 (r = 2.5%). The test so defined was corrected, increasing or decreasing according to the type of company (micro-very small nursery vs. medium-large nursery), to take into account the different riskiness between investments and the various function performed by the rate of return compared to the function of the capitalization rate. Ultimately, the essay tends to decrease in case of security and ease of operation of the company, greater security of income perception, more excellent attractiveness of the fund, more "comfortable" offered by the funds. It happens in reality in the larger and more densely invested nurseries, compared to the micro-nurseries for which a higher rate has been attributed.

For the second analysis, on the other hand, in the literature, the assessment of the economic impacts on companies deriving from the spread of plant diseases is carried out with quantitative methods, such as partial balance analysis, partial balance models, input-output analysis and general equilibrium models. The choice of the most appropriate model depends on the objective of the report, the regional scale, and the availability of data.

Assessment of the economic impact in case of invasion

In the present work, we carried out the assessment of the economic impact and the estimate of the possible damages caused by *Xcc* using the partial balance approach, which made it possible to estimate the profitability variation of ornamental citrus nurseries as a result of the application of potential prevention and action guidelines (Danzì et al., 2020).

The irreversible damage was estimated according to the procedure of lost income, assuming a period following the eradication of the plants and such as to allow the reimplantation and restoration of production conditions, equal to 5 years.

Therefore, transitory income obtained from the difference between the ex-ante income and the ex-post income of the possible infection was calculated.

Therefore, the discounting and the sum of the flow of such annual income related to the period necessary for the restoration of the ex-ante conditions, in addition to the cost of replanting, was then passed.

Table 9 shows the amount of damage per plant and type of nursery, assuming a constant capitalization rate (r = 2.5%), equal to 14.1 EURO /plant for the micro-very small farm and 12.1 EURO /plant for the medium-large company.

About the economic aspect of a possible prevention protocol, the first type suffers more damage due to higher gross profitability composed by non-binding measures and stricter than the provisions of the phytosanitary legislation and the rules on conditionality, designed to reduce the risk of spreading the disease.

The planned interventions concern:

- surveillance and removal of plants or parts of plants;
- careful management of the defense;
- putting in place prevention systems.

The analysis of production costs following

Labels	Small-micro nursery	Medium-large nursery
Economic duration (max)	5 years	5 years
Age of the plants	3 years	3 years
Periods (y) of lack of income	2	2
Average price at nursery per ornamental plant (€)	11.5	10.5
Average production/ha	45,000	60,000
Failed revenue (€)	517,500.00	630,000.00
Failed costs (fertilization, treatements, control, ecc.): 40% of price	4.2	4.2
Lack of annual income, €/plant	7.3	6.3
Impact on n. 1 ornamental lemon plant	14.1	12.1

Source: The impact was determined on the basis of the lack of income discounted to current events: $D = A\frac{(qn-1)}{Rqn}$

Table 9. Evaluation of the economic impact of the introduction of Xcc according to an income approach (2018).

Impact Level	Matherials and costs		Labour and services		Fees and other costs		Total	
	€/plant	Index	€/plant	Index	€/plant	Index	€/plant	Index
O	1.466	**100**	1.806	**100**	1.256	**100**	4.528	**100**
Mild	1.538	**105**	1.822	**101**	1.302	**104**	4.661	**103**
Moderate	1.611	**110**	1.838	**102**	1.347	**107**	4.795	**106**
High	1.683	**115**	1.853	**103**	1.392	**111**	4.929	**109**

Source: Our data elaboration. O = average costs incurred by production companies in 2017, in the absence of Xcc; Mild = the company implements defense and prevention systems according to a defined protocol and undergoes a 10% increase in costs; Moderate = the company implements defense and prevention systems according to a defined protocol and undergoes a 20% increase in costs; High = the company implements defense and prevention systems according to a defined protocol and undergoes a 30% increase in costs.

Table 10. Effects of the adoption of a protocol of prevention from the invasion of *Xcc* (2018).

the adoption of the protocol was carried out through a partial budget comparing the production costs in the situation before those associated with the new management, assuming that the partial modification of the cultivation techniques does not affect the quantity and quality of the seedlings implemented (Table 10).

Conclusion

The ornamental Rutaceae feed a substantial commercial flow on an international level, involving the various producing countries of species similar to the Citrus genus, even if, in some of them, the CBC is present.

The Mediterranean Basin is currently free from the disease, but the relative causative agent *Xcc* is considered to be a quarantine organism for this territory (EU Reg. 2019/2072). The closure of commercial relations from potentially endangered areas is not the tool put in place by EU policy-makers, who, according to the WTO agreements, tend to favor trade by trusting on the functioning of the phytosanitary control systems put in a network.

Given the distance between the Mediterranean basin and the areas in which the bacterium was found (North and South America, Africa, India, and West Asia, and China and East Asia), it is currently unlikely that the path of infection could be the trade of ornamental Rutaceae plants ready for sale. However, the propagation material which has a longer shelf life in the case of transport both within the passenger luggage and with the transport systems used in commercial activities.

So the concrete problem of the introduction of the pathogen exists, and the scientific community is called to evaluate possible damage from invasion to orientate the control policies.

For the determination of the damage caused by the CBC invasion in the Mediterranean Basin, the relative importance of ornamental Rutaceae was initially extrapolated in the context of the ornamental flowers and plants sector, which is not a smooth operation based on official statistics.

Therefore, at the micro level, the most likely production and revenue cost were determined per unit of ornamental plant ready for sale, in a representative area and for a species of ornamental Rutaceae widely cultivated (Timpanaro et al., 2018). Finally, with the income method, a value of probable damage has been determined, estimating the change in the profitability of the ornamental citrus nurseries as a result of the application of possible prevention and action guidelines. All this is also in line with the provisions of the recent European phytosanitary legislation (EU Reg. 2016/2031), which focuses a lot of attention on the traceability of the supply chain.

The irreversible damage was estimated according to the loss of income procedure, assuming a period following the eradication of the plants and such as to allow the replanting and restoration of production conditions, equal to 5 years.

The results show that the application of the guidelines entails a significant increase in production costs, in particular, due to the rise in the cost of materials and quotas and other allocations.

Ultimately, such a change in the management of the nursery, aimed at opposing the arrival of *Xcc* can be implemented only with the introduction of a mechanism to compensate for the effort required by the nursery production companies of ornamental Rutaceae.

In conclusion, the interest of policymakers must be oriented towards a risk of variable invasion according to: type of nursery, with a distinction between a "professional" structure (authorized by the phytosanitary services, also for issuing a passport, which is unlikely to expose itself to any risky imports, to pursue additional profits) and a "hobbyist" structure, which it benefit from the derogation regime and which can be attempted by the possibility of expanding its commercial offer, with imports at risk; type of Rutaceae, with diversity between common and niche ornamental Rutaceae (e.g., Murraya paniculata, Citrus mitis, Coleonema pulchrum, Poncirus trifoliata, Zanthoxylum beecheyanum, Murraya exotica); type of plant material subject to trade (the risk is mainly linked to the propagation material (scions, in particular), easily concealable (in the case of intentional invasion) and potentially able to escape customs controls (especially if placed inside the luggage of apparent tourists); type of trade, distinguishing between traditional and modern forms, represented by multi-channel, electronic and direct distribution formulas for final consumption.

Future research developments will go in the direction of verifying, which market control tool is acceptable for operators and consumers, to counter the invasion of *Xcc* effectively.

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