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A YIELD STABILITY INDEX AND ITS APPLICATION FOR CROP PRODUCTION

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ABSTRACT

A good crop production technology should provide high yields under varying environmental conditions, i.e. keep yield fluctuations small. The magnitude of fluctuations is usually measured by statistical indicators of average dispersion, e.g. the standard deviation. However, while many small fluctuations are usually well tolerated by the farmer, an extreme yield may be a serious risk factor. The present research introduces a yield stability index developed which measures the frequency of extremely high and extremely low yields. The index is tested for 10 countries and 18 crops for 2004-2016, comparing it to 1961-2000, pointing out possible agricultural policy implications.

Keywords: crop yield, fluctuation, risk, time series, yield stability

1. INTRODUCTION

Agriculture – and especially crop production – is very sensitive to weather and other environmental impacts. The efficiency of production technology is measured by crop yield per area, but this is considerably influenced by environmental conditions, anomalies, unexpected stressful events. Therefore yields fluctuate year by year, and the applied technology should be prepared to mitigate adverse environmental impacts. Therefore, with a proper technology the yield fluctuations due to environmental changes is are modest, while an unsuitable technology may result in very low yields even under usual, but unfavourable environmental conditions. Climate change will have a substantial effect on agricultural production. The changing precipitation and heat effects, and especially the increased frequency of extreme weather events may lead to increasing instability of crop yields and require specific technologies to maintain stable food provisions [1].
A proper crop growth technology should be capable of providing reasonably high and stable crop yields under any weather, i.e. it should be prepared to handle dry and wet periods, higher and lower temperatures, and provide reasonable protection against the typical pests or diseases that usually occur in the area of production. At the same time, technological development is expected to result in an increasing trend of crop yields, with annual fluctuations around the trend according to annual environmental variability. The purpose of crop variety selection is to find a variety that produces high yields with sufficient stability in the target environment [2]. To capture both traits Kamidi [2] created a complex index multiplying a measure of the yield performance by a measure of the variability. While the increasing trend of the yields is a welcome fact, the annual fluctuations present a risk for producers. Too low yields clearly lead to low incomes and economic losses instead of a solid profit, but extremely high yields may also have a negative economic impact. With high outputs the market supply may increase well above demand, leading to falling prices and ultimately to low incomes, in spite of high yields, if proper storage facilities are not available at reasonable costs. The association of high yields and lower producer prices was demonstrated by Kovářová et al. [3] regarding sugarbeet production in the Czech Republic, and by Kovářová and Procházková [4] for milk yield and milk price fluctuations, as well as milk turnover changes for 2006-2011.
Tóth-Kaszás et al. [5] analysing emphasise the importance of producer risk aversion as a typical characteristic of small-scale farmers. The crucial issue for them is to find a local market for their products. But demand is limited, therefore overproduction obviously leads to difficulties of sales, and thus, difficulties in achieving profitability.

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The best protection against risks generated by yield instability could be a production technology that provides reasonably stable yields under any weather and environmental conditions typical for the area. Therefore no extremes – high or low – are experienced, the producer can safely plan for the future. The question is how to define the „reasonably stable" yield, i.e. when can the yield fluctuations around the increasing trend be considered „reasonably small". The fluctuation of the time series around the trend is usually measured by various dispersion indicators. The sum of the absolute errors (the absolute value of the difference between the actual value and the trend estimation), the sum of squares of error, the standard deviation, the coefficient of variation (the standard deviation divided by the mean value) are generally used, as is described in any introductory statistical text (see e.g. [2]).

Literature is abundant on assessing intertemporal crop yield stability, or more generally the variability of time series data. The most commonly used method to assess stability is the standard deviation of the data, i.e. the standard deviation of crop yields, although other methods are also used, e.g. the average percent deviation from a trend, either linear or non-linear [7].

Yield stability analyses have been aimed to find the highest yielding varieties, or cropping systems, that are not varying intolerably with changing environmental conditions. However, high yields often go together with higher yield variability. Yield variability can be measured at the level of individual crop varieties, and also at the aggregate national level, i.e., the average yields of all varieties of a given crop grown in a certain area.

According to Piepho [8] cropping systems are considered stable when some variance component is small. However, assessing the risk of a poor yield may be more important than general yield stability, as producers can usually better accept systems that produce high average yield with larger yield variance, than lower yielding systems with small yield variance. Therefore yield stability assessments should consider both the mean yield and yield variance. Piepho [8] emphasises the fact, that measuring the risk of a decreasing yield may be more useful than a quantification of the general level of yield variance. Yield stability measures based on regression fitted to yield series are widely used, with instability measured as the mean square deviation from the regression model [9].

Khalil and Pour-Aboughadareh [9] compare various barley cultivars, assessing their adaptability to specific natural conditions. High adaptability requires high mean yields across environments, with little variability or deviation from the mean yield. They use the coefficient of variation and the sum of squares of deviations around a regression line as measures of variability. Maize experimental data were used by Wang et al. [10] assessed yield variability for paddy rice, maize, wheat and rapeseed over the period 1952-2009 in Yunnan province, China. They determine the trend of each crop yield series, and compute the proportion of the residual values to the estimated trend values. They consider negative residual values as various levels of disaster, but do not consider positive residuals problematic in any sense. Similar trend-based studies were carried out for for the USA and Western Europe in [11-13] and [14].

However, as Bacsi and Vizvári [15], and Vizvári and Bacsi [16] pointed out, a high standard deviation may be the result of a few very extreme fluctuations, but also of many much smaller fluctuations. For a farmer the two situations are completely different. The many small fluctuations in crop yields are well within the range of acceptable variability which the producer can handle, while a few extremely low, or high, yields may create serious economic risk. Bacsi and Vízvári [15] developed a yield risk index which measures the frequency of extremely high or extremely low yields in a time series.

A modified version of this index is the yield stability index [16], which quantifies the level of stability for a yield series, by measuring the proportion of annual yields being reasonably close to the expected trend value within a time period. The two indices – the yield risk index and the yield stability index - were tested for 10 countries and 18 crops for the time period 1961-2000 [15],[16].

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The total world production of these crops is significant, they covered 85% of the crop area in Europe, and 64% in the world in 2010. The present paper, adjusting somewhat the yield stability index, carries out the same analysis for the same crops and countries for the period 2004-2016 with two purposes. One of these is to see the changes in the stability of the crop production, with consideration of climate change and the changing agricultural policies of the EU. The other purpose is to demonstrate the practical relevance and applicability of the yield stability index for the agricultural policy of a country.

2. MATERIALS AND METHODS

The methodology of computing the yield stability index is described in detail in Vizvári-Bacsi [16], the yield risk index is explained in Bacsi-Vízvári [15]. The essence of the calculations, with the proposed adjustments, is briefly summarised below.

Taking a country and a particular crop, annual yields are measured for a given period of years. The trend of these yields is determined by fitting a linear regression equation to these annual yield series (a non-linear trend may as well be fitted if the series justify it better). Then, the fitted line is used to estimate expected yields for each year, and the differences between the expected yield and the actual yield are computed. The core of the analysis is to evaluate these differences, and decide, whether they are large, or tolerably small. However, the differences depend on the general magnitude of the yield series, therefore the 1000 kg/ha difference can be small for sugarbeet, with a typical yield around 60000 kg/ha, while it is very high for rye having a typical yield of about 3000 kg/ha.

In order to make crops and differences comparable, the yield time series were normalised in the following way. Before fitting the trend line each time series is divided by its average value, therefore the normalised time series show the proportion of the actual yield to the average yield of the crop. Then the trend lines are fitted to these normalised series, and the expected normalised yield values are computed. Annual normalised yield residuals are computed as the difference between the normalised value of the actual yield and the estimated trend value computed from the normalised trend equation. This way each residual is measured relative to the magnitude of the actual time series, and thus various crops and countries are made comparable regarding the largeness or smallness of yield fluctuations.

The residuals should be assessed whether they are „small" or „large". For this purpose the normal distribution is used to determine the „tolerably small" and „too large" values. The parameters of the normal distribution are the same as of the residual series (zero expected value and standard deviation of the residual series). Using this normal distribution the residuals are small if at least as many residual values fall in the „vicinity of zero" as is the case for the normal distribution, and therefore less of the residual values fall „far from zero" as for the normal distribution. To define the „vicinity of zero" the range of the normalised residual series is divided into 10 equal intervals. The value of 0 falls into one of the middle segments, usually into the 5th or 6th one. The „vicinity of zero" is defined then as the 4 middle segments, while the 3 lowest and the 3 highest segments are „far from zero".

Because for each crop the yield series of 10 countries were used in the analysis, the minimum and maximum values of the residuals were taken as the minimum and maximum of the 10 countries, for a particular crop. Thus the same range and segments were defined for each country for this crop. Similarly, the standard deviation for the normal distribution of a particular crop was the average of all the residual standard deviations of the 10 countries for this crop, thus the same normal distribution was used for each country for the particular crop.

The final step is to compare the residual distribution and the normal distribution. Taking the proportion of the 13 normalised residual values falling into the four middle segments (FRF – favourable residual frequency, the values in the vicinity of zero), and similarly, the proportion of values from the normal distribution that would fall into the four middle segments (FNF – favourable normal frequency), we can compute the sum of favourable differences (FD) as FD = FRF-FNF.

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Then the proportion of the normalised residual values not falling into the four middle segments (URF – unfavourable residual frequency, values far from zero) and the proportion of the normal distribution not falling into the four middle segments (UNF – unfavourable normal frequency) give the sum of unfavourable differences (UD) as UD = URF-UNF. Note, that FRF+URF=1 and FNF+UNF=1, thus UD =URF−UNF=1−FRF−1+FNF=FNF−FRF= − FD. The adjusted yield stability index is computed as YSI = FD−UD =2 × (FRF−FNF).

The yield stability index defined by Vizvári and Bacsi [16] counted with absolute numbers instead of proportions, therefore the index values depended on the length of the time period analysed. The yield risk index *YRI* [15] applied a division by the length of the data series, which gives the same result as using proportions. The yield risk index used signs opposite as the yield stability index, therefore YRI = − YSI. As YSI=2 × (FRF−FNF), both FRF and FNF are proportion values between 0 and 1, the YSI can take values between -2 and +2, regardless of the crop and the number of years analysed. Using the above methodology the yield stability index is computed for 10 countries and 18 crops for the time period 2004-2016, based on yield data of the FAO database [17]. The following countries were chosen: Canada (CA), Denmark (DK), France (FR), Hungary (HU), Italy (IT), The Netherlands (NL), Turkey (TU), The United Kingdom (UK), USA (US) and Japan (JP). The 18 crops selected for the analysis are: barley, wheat, maize, rice, rye, oats, sunflower, rapeseed, potatoes, sugarbeet, hops, green peas, onions, cabbages, spinach, carrots, cucumbers and soybean. Results of the time period 2004-2016 were compared to the period of 1961-2000 using the results of [16], to see whether any technological progress is detectable.

3. RESULTS AND DISCUSSION

The average yields for each crop widely differ among the countries, depending on the environmental conditions and production technologies – including intensive and extensive farming (Figure 1). The 13-year average cucumber yields are 44 times higher in the Netherlands than in the USA, and spinach yields are also 4.25 times higher in France than in Denmark.

As it was described in the methodology section, the annual yield series of each country and each crop are normalised (i.e. divided by the 13-year average), and linear trends are fitted to each normalised series. Then the residual time series for each crop in each country are computed. As the normalisation process makes fluctuations comparable, these standard deviations can be used to compare the yield variabilities of crops and countries.

Taking the average of standard deviations of each crop across countries, the highest standard deviation was found for spinach in Denmark (0.517), followed by cucumber in France (0.337). For most crops and countries the standard deviation remained under 0.1. Turkey and Italy had the smallest average residual standard deviations across crops (0.063).

As described above, the residual time series of the crops in the ten assessed countries are compared to the normal distribution of zero expected value and average standard deviations of each crop. Then the occurrences of favourable and unfavourable deviations are computed, and the Yield Stability Index is determined for each crop and each country. To facilitate comparison, the YSI values for the years 1960-2000 are presented using the data of Vízvári and Bacsi [16] with the adjustments described in the methodology (Table 1), and the results for the period 2004-2016 are presented in Table 2.

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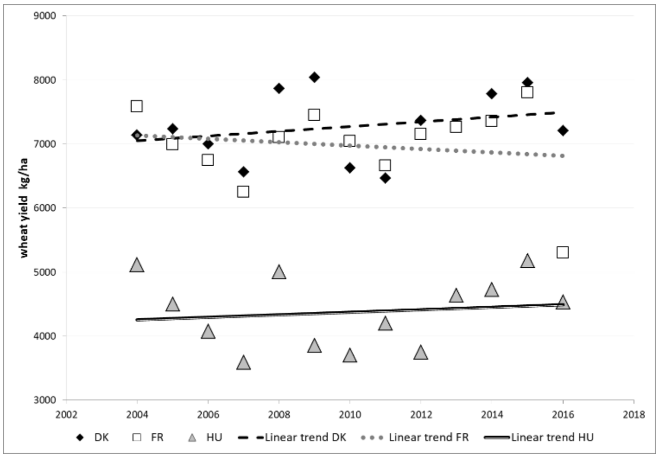

Figure 1:Annual wheat yields in Denmark, France and Hungary 2004-2016 (from data of [17])

Table 1: Yield Stability Index Values, 1961-2000
(Authors' own computations based on [16])

YSI	CA	DK	FR	HU	IT	NL	TU	UK	US	JP	*Mean*
barley	0.081	0.006	0.081	-0.245	0.006	0.056	0.031	0.081	0.081		**0.019**
wheat	-0.028	0.047	0.122	-0.303	0.072	0.047	-0.078	0.072	0.072		**0.003**
maize	0.078		0.078	0.003	0.078	-0.072	0.078	-0.297	-0.172		**-0.028**
rice			-0.088	-0.288	0.013		0.088		0.113	0.088	**-0.013**
rye	-0.004	0.046	0.121	-0.129	0.096	0.046	0.021	0.046	-0.029		**0.024**
oats	0.092	-0.083	0.067	-0.433	-0.008	-0.008	0.092	0.092	0.067		**-0.014**
sunflower	0.141		0.216	0.041	0.216		0.241		0.166		**0.170**
rapeseed	0.049	-0.001	0.024	0.024	-0.051	0.049	-0.076	0.024			**0.005**
potatoes	0.102	-0.023	-0.023	-0.198	0.102	-0.023	0.002	0.052	0.102		**0.011**
sugarbeet	0.074	0.049	0.099	-0.101	0.049	-0.001	-0.101	-0.101	0.149		**0.013**
hops	0.029		-0.021	0.104				0.204	-0.146		**0.034**
green peas	0.042	-0.008	0.042	-0.083	-0.108	0.042	0.017	0.017	-0.033		**-0.008**
onions	0.009	-0.117	-0.042	-0.317	0.184	-0.117	0.159	0.009	0.184		**-0.005**
cabbages	-0.067	-0.217	0.108	-0.242	0.083	0.108	0.083	-0.317	0.108		**-0.039**
spinach	0.112	0.012	0.062	-0.013	0.162	-0.038	0.012		-0.238	-0.063	**0.001**
carrots	0.090	-0.035	0.115	-0.110	0.115	-0.160	-0.260	-0.035	0.165		**-0.013**
cucumbers	-0.048	-0.423	-0.023	-0.148	0.077	-0.173	0.077	0.077	0.077		**-0.057**
soybean	0.088		-0.262	-0.112	0.088	0.000	-0.087		0.088	0.063	**-0.017**
Mean	**0.049**	**-0.058**	**0.038**	**-0.142**	**0.069**	**-0.016**	**0.017**	**-0.006**	**0.044**	**0.029**	

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The Yield Stability Index for the major cereals is positive for most of the countries. Hungary is the only country in which it is negative for both 2004-2016 and 1960-2000, although the maize index value is slightly improved since 2004, the EU-accession (Table 3 and Figure 2).
For France, on the contrary, YSI values decreased for barley, wheat and maize after 2004, and only rice showed a positive change. Italy has experienced a considerable improvement of YSI for all the four presented crops, yields have become more stable than they were before 2000.
Table 3 presents the changes of the yield stability computed by the following formula:

$$YSI_{change} = YSI_{(2004\text{-}2016)} - YSI_{(1961\text{-}2000)} \quad (1)$$

Positive values indicate that yields have become more stable after 2004 than they were before 2000.
In most of the countries many crops show improved yield stability, but none of the countries achieved improved yield stability for all the 18 crops. There is no crop, that has better yield stability for all the countries, but the YSI of cucumbers improved everywhere except in France, and the YSI of cabbages improved in 8 countries (the Netherlands and Japan are the exceptions). On the contrary, for sunflower the yield stability improved only in one country (Hungary), the other five producers cound not achieve higher YSI values than before 2000 (Table 3).

Table 2: Yield Stability Index Values, 2004-2016

YSI	CA	DK	FR	HU	IT	NL	TU	UK	US	JP	*Mean*
barley	0.110	0.110	0.033	-0.198	0.187	0.033	-0.121	0.187	-0.044	-0.044	**0.025**
wheat	0.176	0.022	-0.132	-0.285	0.176	0.099	0.176	0.022	0.176	-0.132	**0.030**
maize	0.233	-0.383	0.079	-0.152	0.156	-0.152	0.079		0.002	0.233	**0.010**
rice			-0.034	-0.111	0.197		0.043		0.197	0.120	**0.068**
rye	0.152	0.229	0.229	-0.078	0.152	-0.001	0.152	-0.386	0.076		**0.058**
oats	0.027	-0.049	-0.049	-0.203	0.181	-0.280	0.027	0.181	0.104	0.104	**0.004**
sunflower	-0.171		0.060	0.060	0.214		-0.017		0.060		**0.034**
rapeseed	0.141	0.141	-0.013	-0.167	-0.013	-0.167	0.218	0.141	0.064	-0.167	**0.018**
potatoes	0.032	-0.045	-0.045	-0.045	0.032	0.032	0.032	-0.199	0.263	0.032	**0.009**
sugarbeet	0.105	0.028	0.259	-0.049	-0.049	0.182	0.105	-0.280	0.182	0.105	**0.059**
hops			0.058	-0.173				-0.096	0.212	-0.404	**-0.081**
green peas	0.108	-0.200	0.108	0.031	0.031	0.108	-0.046	-0.277	-0.431	0.108	**-0.046**
onions	-0.030	0.124	-0.107	-0.107	0.201	0.047	0.124	-0.030	0.124	-0.030	**0.032**
cabbages	0.194	-0.037	0.194	0.040	0.194	-0.422	0.194	0.040	0.117	-0.422	**0.009**
spinach	-0.044	-0.506	0.033	0.033	0.033	0.033	0.033		0.033	0.033	**-0.036**
carrots	-0.390	0.072	0.072	-0.467	-0.005	-0.005	0.072	0.149	0.149	0.149	**-0.021**
cucumbers	0.027	-0.358	-0.358	0.027	0.104	0.181	0.181	0.181	0.181	0.181	**0.035**
soybean	0.128		0.051	-0.180	-0.026		0.128		0.128	-0.026	**0.029**
Mean	**0.050**	**-0.061**	**0.024**	**-0.112**	**0.104**	**-0.022**	**0.081**	**-0.028**	**0.088**	**-0.010**	

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The Yield Stability Index developed and computed here can have two main possible ways of application. One is of a methodological importance. The YSI provides a different, and better, way of assessing crop yield stability than formerly applied simple methods. It is relatively easy to compute, it differentiates between many small deviations and few large ones, and accounts for both low and high yield extremes as instability. This approach is more reasonable for farmers than using the standard deviation or coefficient of variation, because the latter two consider small and large deviations with equal importance.

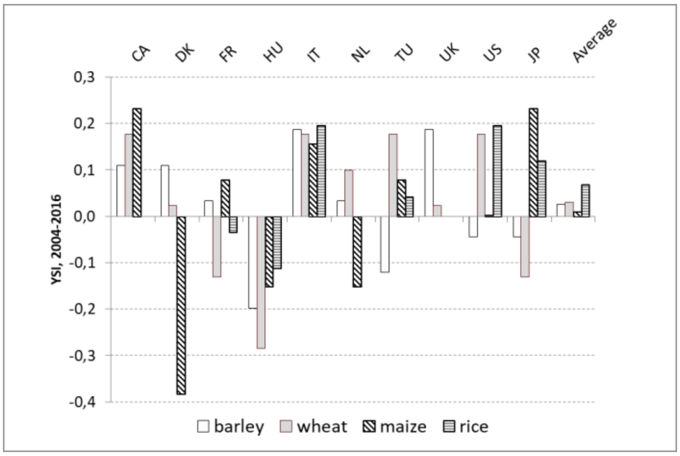

Figure 2: The Yield Stability Index Values for Selected Crops in 2004-2016 (Authors' own construction based on the data of Table 3.)

Comparing the YSI values to the coefficients of variation (CV) the two indicators give a different judgement on crop yields. The CV values are positive, and higher CV means higher variability (higher variance relative to the average) of crop yields. The YSI measures the opposite, the stability of yields, therefore higher YSI means better stability, i.e. less variability. Therefore CV and YSI should have an inverse relationship.

As is presented in Figure 3 the CV values plotted against YSI values pooling all countries and all crops (i.e. 18 x 10 = 180 value pairs) show this negative relationship, but a fitted regression line is far from showing a perfect fit. This indicates that CV and YSI often give different judgments on particular crops in particular countries. The correlation coefficient between CV and YSI is R= −0.580, which is not particularly strong, though negative. As is seen in the figure, for some crops and countries a rather low CV (low variability) is accompanied by a small negative YSI (high variability) as for carrots in Hungary and hops in Japan, or a high CV (high variability) goes together with a positive and high YSI (low variability), e.g. rapeseed in Turkey. This demonstrates the practical relevance of computing YSI, and using it instead of CV for a refined assessment of stability.

The second application is relevant for decision making purposes. This application is based on the actual computed values of YSI – which, due to the methodology, are directly comparable between countries, between time periods, and between crops. A totally unstable crop would have its YSI value near -2.0, while a very stable crop would have YSI close to 2.0. Comparing the actual computed YSI index values to these theoretical limits the stability level of a crop in a country can be directly assessed. Positive YSI values indicate that the assessed crop and its production technology are well suited to the environmental conditions of the country and the present technology can maintain the yield trends with no risk. Temporal changes in YSI show the technological changes for a crop in the country. Thus a positive change in the index indicates that research and development (R&D) directed to production technology is successful for

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the crop, and the crop production system can be better adapted to the environmental conditions of the country.

Table 3: Change of Yield Stability Index (YSI change) from 1961-2000 to 2004-2016

YSI $_{change}$	**CA**	**DK**	**FR**	**HU**	**IT**	**NL**	**TU**	**UK**	**US**	**JP**	***Mean***
barley	0.029	0.104	-0.048	0.047	0.181	-0.023	-0.151	0.106	-0.125	-0.044	**0.008**
wheat	0.204	-0.025	-0.254	0.018	0.104	0.052	0.254	-0.050	0.104	-0.132	**0.028**
maize	0.155	-0.383	0.001	-0.155	0.078	-0.080	0.001	0.297	0.174	0.233	**0.032**
rice			0.053	0.177	0.184		-0.045		0.084	0.032	**0.081**
rye	0.156	0.183	0.108	0.050	0.056	-0.048	0.131	-0.432	0.104		**0.034**
oats	-0.065	0.034	-0.116	0.230	0.190	-0.272	-0.064	0.089	0.037	0.104	**0.017**
sunflower	-0.311		-0.156	0.019	-0.002		-0.258		-0.106		**-0.135**
rapeseed	0.092	0.142	-0.037	-0.191	0.038	-0.216	0.294	0.117	0.064	-0.167	**0.013**
potatoes	-0.070	-0.022	-0.022	0.153	-0.070	0.055	0.030	-0.251	0.161	0.032	**0.000**
sugarbeet	0.031	-0.021	0.160	0.052	-0.098	0.183	0.206	-0.179	0.033	0.105	**0.047**
hops	-0.029		0.079	-0.277				-0.300	0.358	-0.404	**-0.096**
green peas	0.066	-0.192	0.066	0.114	0.139	0.066	-0.063	-0.294	-0.397	0.108	**-0.039**
onions	-0.039	0.240	-0.065	0.210	0.017	0.163	-0.035	-0.039	-0.060	-0.030	**0.036**
cabbages	0.261	0.180	0.086	0.282	0.111	-0.530	0.111	0.357	0.009	-0.422	**0.044**
spinach	-0.156	-0.517	-0.029	0.046	-0.129	0.071	0.021		0.271	0.096	**-0.036**
carrots	-0.480	0.107	-0.043	-0.356	-0.120	0.155	0.332	0.184	-0.016	0.149	**-0.009**
cucumbers	0.075	0.066	-0.334	0.175	0.027	0.354	0.104	0.104	0.104	0.181	**0.085**
soybean	0.040		0.313	-0.068	-0.114		0.215		0.040	-0.089	**0.048**
Mean	**-0.002**	**-0.007**	**-0.013**	**0.029**	**0.035**	**-0.005**	**0.064**	**-0.021**	**0.047**	**-0.015**	**0.013**

However, the actual YSI and the change of YSI both may be important for decision makers. A positive YSI and a positive change of YSI means, that the crop and its production technology are well adapted to the environment, and there are possibilites of further improvement. Then this crop is a prospective success in the particular country. On the contrary, a negative, and decreasing YSI means that the crop is not suitable, and improvement cannot be seen, therefore either the crop should be abandoned as too risky, or a profound change of the technology should be introduced.

With negative but increasing YSI a formerly less well adapted production technology seems to be improved, and development goes hopefully in the right direction. The situation, when YSI is positive but decreasing should raise the attention of decision makers. The current technology is still suitable, but the risk of higher variability is increasing, therefore an improvement for the technology must be looked for. In an extreme case, this tendency may indicate that long-term climate change makes a formerly well adapted crop unsuitable in the future. These possibilities should be taken into account when deciding about cropping structures and R&D directions.

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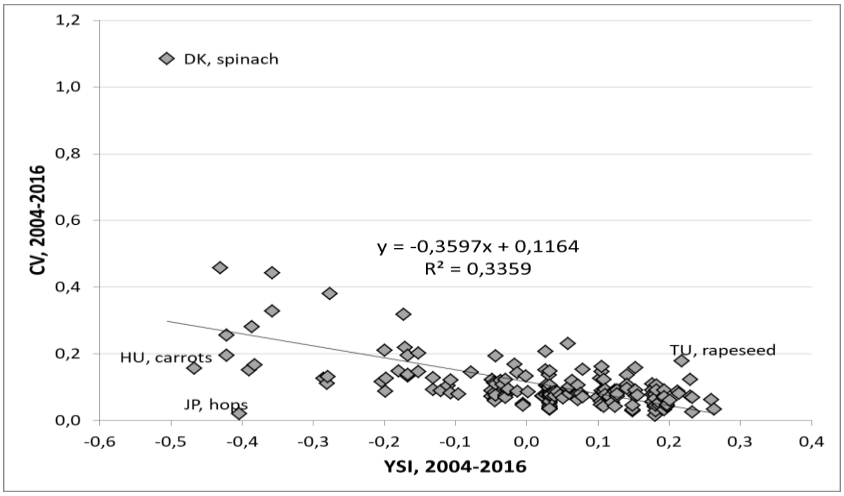

Figure 3: The Coefficients of Variation and YSI for all countries and all crops in 2004-2016.

4. CONCLUSIONS

The yield stability index measures only deviations of yields from the yield trend, but it does not say anything about the actual level of the yield, or the direction of the trend (increasing or decreasing). Therefore, for decision makers both the trend of the yields, and the YSI value should be taken into account. The optimal cropping technology should have high yields (high slope of a yield trend) with low variability (high YSI).
This may have an implication for the agricultural support policies of countries. Countries with a general support scheme for agricultural producers can provide a protection against risk for the farmers. Intervention schemes for overproduction or insurance structures against very low yields may make the agricultural sector less sensitive to the possible risks related to yield variability, and this may decrease the sector's motivation to improve production technologies. Public subsidies fro the farming sector are very influential both in the USA and in the EU [13]. Although this aspect was not researched in this paper, four of the six assessed EU-member states produced negative average changes in YSI values (Italy and Hungary were the only countries with positive average change). The highest stability improvements were seen in the USA and Turkey, although probable causes or explanations are beyond the scope of the present paper. With decreasing agricultural support the farmers in the EU will have to be more conscious of introducing risk-mitigating technologies.

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