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No-tillage system participatory quality index

Tiago S. Telles[1], Ana J. Righetto[1], Marco A. P. Lourenço[1] & Graziela M. C. Barbosa[1]

[1] Instituto Agronômico do Paraná. Londrina, PR, Brasil. E-mail: telles@iapar.br (Corresponding author) - ORCID: 0000-0001-5817-3420; ajrighetto@gmail.com - ORCID: 0000-0003-4879-0710; marcpelisson@gmail.com - ORCID: 0000-0001-6843-8840; graziela_barbosa@iapar.br - ORCID: 0000-0003-2116-4736

ABSTRACT: The no-tillage system participatory quality index aims to evaluate the quality and efficiency of soil management under no-tillage systems and consists of a weighted sum of eight indicators: intensity of crop rotation, diversity of crop rotation, persistence of crop residues in the soil surface, frequency of soil tillage, use of agricultural terraces, evaluation of soil conservation, balance of soil fertilization and time of adoption of the no-tillage system. The aim of this study was to assess the extent to which these indicators correlate with the no-tillage system participatory quality index and to characterize the farmers who participated in the research. The data used were provided by ITAIPU Binacional for the indicators of the no-tillage system participatory quality index II. Descriptive analyses were performed, and the Pearson correlation coefficient between the index and each indicator was calculated. To assess the relationship between the indicators and the farmers' behavior toward the indicators, principal component analysis and cluster analysis were performed. Although all correlations are significant at p-value ≤ 0.05, some correlations are weak, indicating a need for improvement of the index. The principal component analysis identified three principal components, which explained 66% of the variability of the data, and the cluster analysis separated the 121 farmers into five groups. It was verified that the no-tillage system participatory quality index II has some limitations and should therefore be reevaluated to increase its efficiency as an indicator of the quality of the no-tillage system.

Key words: farmers, conservation agriculture, crop rotation, soil and water conservation, sustainable agriculture

Índice de qualidade participativo do sistema plantio direto

RESUMO: O índice de qualidade participativo do sistema plantio direto tem o intuito de avaliar a qualidade e a eficiência do manejo do solo quanto ao uso do sistema plantio direto, sendo formado pela soma ponderada de oito indicadores: intensidade da rotação de culturas, diversidade da rotação de culturas, persistência de resíduos na superfície do solo, frequência de preparo do solo, uso de terraços agrícolas, avaliação da conservação do solo, fertilidade balanceada do solo e tempo de adoção do sistema plantio direto. O objetivo deste estudo foi verificar com qual intensidade esses indicadores se correlacionam com o índice de qualidade participativa do sistema plantio direto e caracterizar os produtores rurais que participaram da pesquisa. Foram utilizados dados da ITAIPU Binacional, referentes ao índice de qualidade participativo do sistema plantio direto II. Foram realizadas análises descritivas e foi calculado o coeficiente de correlação de Pearson entre o índice e cada indicador. Com o intuito de verificar a relação dos indicadores entre si e dos produtores rurais que participaram da pesquisa com os indicadores, foram realizadas as análises de componentes principais e de agrupamento. Apesar de todas as correlações serem significativas ao nível de p-value ≤ 0.05, algumas correlações foram fracas, indicando a necessidade de mudanças para aperfeiçoar o índice. Com a análise de componentes, foram identificados três componentes principais, que explicam 66% da variabilidade dos dados e com auxílio da análise de agrupamento, os 121 produtores foram separados em cinco grupos. Verificou-se que o índice de qualidade participativo do sistema plantio direto II apresenta algumas limitações e, portanto, deve ser reavaliado para aumentar sua eficiência como indicador de qualidade do sistema plantio direto.

Palavras-chave: produtores rurais, agricultura conservacionista, rotação de culturas, conservação do solo e da água, agricultura sustentável

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Introduction

The no-tillage system (NTS), also known as conservation agriculture (CA) (Kassam et al., 2009), represents a set of agricultural practices supported on three pillars: permanent soil cover, minimum soil tillage and crop rotation (Friedrich et al., 2012; Derpsch et al., 2014; Ward et al., 2018). In Brazil, it is considered the most efficient farming system for water erosion control in areas with annual crops.

Despite the benefits of NTS on the effective control of soil erosion, other soil conservation practices are necessary, such as contour farming and the use of agricultural terraces (Didoné et al., 2014; Londero et al., 2018; Telles et al., 2019). However, because farmers believed that erosion processes would be fully controlled in no-tillage areas, many of them eliminated all or part of the agricultural terraces and abandoned contour farming (Silva & Maria, 2011), which resulted in low-quality NTS (Denardin et al., 2008; Didoné et al., 2017).

In the 1990s, the Instituto Agronômico do Paraná (IAPAR - Agricultural Research Institute of Paraná State), in partnership with ITAIPU Binacional, conducted a diagnosis of the quality of NTS (Calegari et al., 2014). The results indicated that the NTS adopted by the farmers did not meet the basic principles of this farming system. Therefore, the term NTS with quality emerged (Casão Junior et al., 2006).

To evaluate the quality of NTS, the Federação Brasileira de Plantio Direto e Irrigação (FEBRAPDP - Brazilian No-Tillage and Irrigation Farmers' Federation), together with ITAIPU Binacional, developed the no-tillage system participatory quality index (IQP), a methodology based on a set of indicators related to the efficiency of the management, aiming at the sustainability of the production systems of farmers in a given region. The index underwent some modifications and is currently in its second version, called IQP2.

In this context, the aim of the present study was to evaluate whether IQP2 is an adequate index to assess the quality of NPS and to determine whether a statistically significant relationship exists between the IQP2 and its indicators. Furthermore, farmers' behavior concerning the results of the IQP2 were analyzed.

Material and Methods

The area considered in the study was the Paraná III basin (BP3), located between latitudes 24° 1' S and 25° 35' S and longitudes 53° 26' W and 54° 37' W. It is distributed in 29 municipalities: 28 located in the Western Paraná mesoregion and one in the Southern Mato Grosso do Sul.

The BP3 comprises 8000 km^2 in which dozens of tributaries flow directly into the Paraná River, where the Itaipu lake is located, at the confluence with the Iguaçu river. The BP3 is located in Western Paraná and the Southern Mato Grosso do Sul. It is a region rich in natural resources and biodiversity, with an abundance of water and excellent soils; it is known for its high agricultural productivity, where modern, mechanized, intensive and technologically advanced agricultural systems are used (Fuentes-Llanillo et al., 2006). The region is composed of basaltic rocks (Serra Geral Formation) and rocks of arenite origin (Caiuá Formation sandstone), in addition to presenting plateaus and terrains with soft slopes towards the west (Maack, 1981).

The IQP is a participatory methodology developed to evaluate the quality of the NTS of a farm while considering each one of the fields that compose the farm. The index has the term "participatory" in its name because the microbasin farmers developed the questionnaire through meetings moderated by technicians and experts from FEBRAPDP and ITAIPU Binacional. It is an indicator that analyzes the actions of the farmer taken to improve the quality of the production system, with this knowledge being used to provide recommendations for the region, as defined by Casão Júnior et al. (2006). This index was built through committees based on the pillars of NTS, which is based on conservation agriculture associated with the best soil and water management practices (Laurent et al., 2011). The strategy of the IQP was to integrate the technical-scientific community with the voluntary participation of the farmers in the construction of a comprehensive questionnaire that was easy to understand and self-applicable, i.e., the farmer must be able to self-evaluate his/her own field across the questions (Roloff et al., 2011).

Initially, the IQP was applied to six BP3 microbasins, in a program called Cultivando Água Boa (cultivating good water): Ajuricaba, Buriti, Facão Torto, Pacuri, Sanga Mineira and Toledo, in Paraná, Brazil. In the first version, used between 2010 and 2012, the results revealed a low-quality NTS, with the simplification and abandonment of soil conservation techniques; abandonment of the practice of crop rotation and permanent soil cover; soil tillage; removal of agricultural terraces; up and down slope soil tillage; and lack of pest control. A good quality NTS was found in only 10% of the farms. The limitations of NTS and the factors that limited its effectiveness in the questionnaire were the lack of knowledge by the farmers of the set of techniques that compose this system (Motter & Almeida, 2015). Given the results, the methodology needed revision, which gave rise to IQP2.

Thus, in this study, the data provided by ITAIPU Binacional for the IQP2 indicators were used, and the questionnaires were applied between 2014 and 2017 in BP3. The data included 206 fields from 121 farmers in microbasins designated by the Cultivating Good Water program. The information is available in the Web Platform-No-tillage System, which shows the results of the IQP2 assessment.

The questionnaire allows eight indicators to be determined: intensity of crop rotation (IR), diversity of crop rotation (DR), persistence of crop residues in the soil surface (PR), frequency of soil tillage (FP), use of agricultural terraces (TE), evaluation of soil conservation (CA), balance of soil fertilization (FE) and time of adoption of the no-tillage system - NTS (TA).

The IQP2 is the result of the weighted sum of the eight indicators, where the weight is 1 or 1.5, and the indicator values range from 0 to 1, according to the farmer's response. Furthermore, each IQP2 indicator has a critical value, which indicates whether the farmer is above or below of what would be minimally expected for the aspects diagnosed for field management.

Table 1 shows a brief description of the three indicators related to crop rotation, the indicator related to soil tillage

Table 1. Indicators related to crop rotation and frequency of soil tillage

Indicators	Input data	Unit	Baseline	Formula	Value Critical	Value Ideal	Weight
IR	Months with live cover	month	36	IR = NM/36	0.75	1	1.5
DR	Different families in crop rotation	family	03	DR = FD/3	0.67	1	1.5
PR	Number of grasses in rotation	grass	06	PR = GR/6	0.50	1	1.5
FP	Interval between soil tillage	year	12	FP = IBP/12	0.50	1	1.5
TA	Time of adoption	year	25	TA = T/25	0.30	1	1.0

IR - Intensity of crop rotation; DR - Diversity of crop rotation; PR - Persistence of crop residues; FP - Frequency of soil tillage; NM - Number of months with live soil cover; FD - Different families in rotation; GR - Number of grasses in rotation; IBP - Interval between soil tillage (years); TA - Time of adoption of no-tillage system; T - Time of adoption

and the indicator that addresses the time of adoption of NTS. The first four are the indicators with the greatest weight for the calculation of IQP2, with a weight of 1.5. The adoption time indicator has a weight of 1.0. The crop rotation indicators are IR, DR and PR, and these are related, respectively, to the time of live soil cover, the different crop families and the different grasses used in the production system. The indicator of soil tillage is FP, which is related to soil management with machines within a period of 12 years. The indicator of time of adoption of NTS is the TA, which uses a period of 25 years as the baseline, so that the historical record of NTS in the BP3 region is considered.

Table 2 shows the indicators related to soil conservation, which included the TE and CA. Both indicators have a weight of 1 in terms of IQP2 score. TE is related to terracing and possible overflowing of terraces on the field evaluated and CA indicates the existence or absence of signs of erosion, soil compaction and contour seeding and spraying.

Table 3 describes the FE indicator, which refers to fertilization. It is an indicator with a weight of 1 in the IQP2, and its score is determined by the consideration of whether the farms use organic manure or not.

According to the FEBRAPDP, on the basis of the IQP2 score, the farmers can be classified as follows: very good, when the IQP2 score is greater than or equal to 8.51; good, when the IQP2 score is between 6.51 and 8.50; regular, when the score is between 4.51 and 6.50; and, poor, when the score is less than or equal to 4.50.

First, descriptive statistics of IQP2 and the eight indicators that compose it were calculated to provide mean, median, minimum and maximum values. To identify the existence of a relationship between IQP2 and each of the indicators, the Pearson correlation coefficient was calculated. With respect to the coefficients, values below 0.30 were considered weak correlations; values between 0.30 and 0.70, moderate correlations; and values above 0.70, strong correlations.

Table 3. Indicator referring to balance of soil fertilization - FE (long-term)

<table>
<tr><th colspan="4">Input data</th><th>Formula</th><th>Critical</th><th>Ideal</th><th>Weight</th></tr>
<tr><td colspan="8">With use of manure</td></tr>
<tr><td colspan="4">Operations performed</td><td rowspan="6">FE = ∑ IFEi/2</td><td rowspan="6">0.5</td><td rowspan="6">1</td><td rowspan="6">1</td></tr>
<tr><td colspan="2">WSA</td><td colspan="2">WoSA</td></tr>
<tr><td>LM</td><td>CF</td><td>UMW</td><td>UMWo</td></tr>
<tr><td>0.5</td><td>0.5</td><td>1</td><td>0.5</td></tr>
<tr><td colspan="4">Maximum score for use of manure = 1</td></tr>
<tr><td colspan="4">IFEi = indicator of fertilization i</td></tr>
<tr><td colspan="8">Without use of manure</td></tr>
<tr><td colspan="4">Operations performed</td><td rowspan="5">FE = ∑ IFEi/1</td><td rowspan="5">0.5</td><td rowspan="5">1</td><td rowspan="5">1</td></tr>
<tr><td colspan="4">WSA</td></tr>
<tr><td colspan="2">LM</td><td colspan="2">CF</td></tr>
<tr><td colspan="2">0.5</td><td colspan="2">0.5</td></tr>
<tr><td colspan="4">IFEi = indicator of fertilization i</td></tr>
</table>

WSA - Based on results from soil analysis; WoSA - Without consideration of the results from the soil analysis; LM - Liming; CF - Chemical fertilization; UMW - Use of organic manure with application control and nutrient balance; UMWo - Use of organic manure with application control and nutrient balance

In addition, principal component analysis (PCA) was performed and involved the construction of new variables on the basis of linear combinations of the original variables (Nakamura et al., 2013). Only the IQP2 indicators with moderate and strong correlation were considered when performing the PCA, and the scores for the 121 farmers were used. In the cases where the farmers had more than one field analyzed, the weighted average of the scores obtained and the sizes of the fields were used. To select the number of PCA components, the Kaiser criterion was used (Kaiser, 1958); in which selects all principal components with eigenvalues equal to or greater than 1. Once the components were selected in the PCA, cluster analysis was performed according to the Ward method, to form groups of homogeneous individuals (Lima et al., 2010). According to Nakamura et al. (2013), the Ward method is the most widely used method for cluster analysis because of the strong statistical appeal involved in the calculation process; this process uses the analysis of variance to perform the clustering of individuals, which are the fields

Table 2. Indicators of soil conservation (long-term)

<table>
<tr><th rowspan="2">Indicators</th><th colspan="4" rowspan="2">Input data</th><th rowspan="2">Formula</th><th colspan="2">Value</th><th rowspan="2">Weight</th></tr>
<tr><th>Critical</th><th>Ideal</th></tr>
<tr><td rowspan="2">TE</td><td colspan="3">With TE
(number of overflows in 5 years)</td><td>Without TE</td><td rowspan="2">TE = ITE/1</td><td rowspan="2">0.50</td><td rowspan="2">1</td><td rowspan="2">1</td></tr>
<tr><td>0 or 1
ITE = 1</td><td>2 or 3
ITE = 0.5</td><td>>3
ITE = 0</td><td>ITE = 0</td></tr>
<tr><td rowspan="2">CA</td><td colspan="2">Contour farming operations</td><td>Compacted soil</td><td>Without erosion</td><td rowspan="2">CA = ∑IC/4</td><td rowspan="2">0.50</td><td rowspan="2">1</td><td rowspan="2">1</td></tr>
<tr><td colspan="2">IC = 0.7 (Seeding)
IC = 0.3 (Spraying)</td><td>IC = 2 (no)
IC = 1 (headwaters)
IC = 0 (entire farm)</td><td>IC = 1 (yes)
IC = 0 (no)</td></tr>
</table>

TE - Use of agricultural terraces; CA - Evaluation of soil conservation; ITE - Score based on the number of overflows in 5 years; IC - Score based on contour farming operations, compacted soil and erosion in this case. The generalized Euclidean distance was used to apply the Ward method (hierarchical cluster analysis), and the scores obtained by the PCA were used for the clustering.

The R 3.2.2 software was used for the statistical analyses, and ArcGIS was used for constructing the maps.

Results and Discussion

Table 4 shows the results of the descriptive statistics of the IQP2 and the eight indicators that compose it. The IR and CA were the only indicators that did not have a score of zero for any farmer. Furthermore, for all indicators, at least one farmer had a maximum score, and on average, only the DR was below the critical value. With respect to the median, with the exception of the DR indicator, 50% of the fields were above the critical value in the others indicators. For IQP2, the lowest score was 3.317, the maximum score was 9, and half of the fields scored above 6.795.

The Pearson's correlation revealed that the IR indicator was significant with p-value ≤ 0.05, and the correlations with the other indicators were significant with p-value ≤ 0.01. The strongest correlation identified was between IQP2 and FP (0.76), and the weakest correlation was for IQP2 with the IR indicator (0.15). Although all correlations are significant, considering p-value ≤ 0.05, the values obtained between IQP2 and the indicators IR and CA are considered weak. Only the FP had a strong correlation with IQP2, while the other indicators had a moderate correlation, with a correlation of 0.36 with DR, 0.49 with PR, 0.52 with TE, 0.34 with FE, and 0.58 with TA. The eight indicators were expected to have at least a moderate correlation with the IQP2 score because this score is formed by the weighted sum of the indicators. Thus, the results are not as expected.

Nunes (2017) also conducted a study involving the IQP2 and its eight indicators but with 40 fields, and the results showed that the IQP2 was weakly correlated with the DR, CA, and FE; moderately correlated with the IR, TE, and TA; and strongly correlated with the PR and FP. These results are slightly different from those in the present study, but this is expected given the sampling differences.

Notably, the principles of conservation agriculture include minimum tillage (no tillage), crop rotation and soil cover maintenance (Brown et al., 2017; Dougill et al., 2017; Kassam et al., 2009). The IQP2 is an index used to assess the level of adoption of conservation practices by farmers and to qualify their production system. Thus, the results obtained in the correlation analysis indicate that IQP2 is, in general, efficient in quantifying and qualifying the quality of conservation agriculture.

Based on PCA, performed for the DR, PR, FP, TE, FE and TA indicators, three principal components (PC) were extracted, whose eigenvalues were 1.81, 1.13 and 1.03, and the three components together explained 66% of the original data variance. With the number of components defined, the loading of each of the six indicators in each of the three components was calculated (Table 5). Higher the loading value was, greater the effect of the indicator on the main component. Thus, for PC1, the indicators with the greatest impact were FP and TA, forming the FP + TA component. For PC2, high loading was present for the PR indicator, and this component was called the PR component. The third component had high loading for the FE indicator and, thus, was called the FE component.

Cluster analysis was performed with the PCA components, with the 121 farmers being divided into five groups. Table 6 shows the mean and standard deviation of the IQP2 and its indicators for each group formed by the cluster analysis. Cluster 1 comprised 11 farmers, all of whom had a score below the critical value for the IR indicator, and the IQP2 score ranged between 5.2 and 7.97, making it the group with the highest variability in the index values. Cluster 2 is formed by 52 farmers, all with IQP2 scores classified as good, and was the group with the highest means for the indicators FP, TE, CA, and TA. Cluster 3 is composed of 24 farmers, with IQP2 scores ranging from 4.98 to 7.04 and the highest mean for the FE indicator. Cluster 4 consist of 7 farmers, all with a score of 0.67 for DR and with a low score for PR. In addition, the farmers of this cluster had an IQP2 score classified as regular. Cluster 5 is composed of 27 farmers, with scores below 0.67 for the DR indicator and with more than 2/3 of the farmers exhibiting a poor score for the other indicators. Figure 1 shows a map of the BP3 with the 121 farmers divided according to the results of the cluster analysis.

In summary, the IQP2 has some limitations related to the relative importance and significance of some of its indicators. That is because some of the indicators are weakly correlated with IQP2 but are important items in its composition, they need to be reviewed. Thus, this is a differential of the IQP2, being a more effective index and low cost, allowing an evaluation of the quality of the NTS.

Several soil quality indicators that are directly linked to soil management exist and have been developed on the basis

Table 5. Loading value of each indicator in the principal components

Indicators	PC1	PC2	PC3
DR	0.52	-0.53	0.29
PR	0.04	0.85	0.35
FP	0.72	0.28	0.06
TE	0.57	-0.02	-0.53
FE	0.47	-0.15	0.66
TA	0.70	0.14	-0.31

PC - Principal components; DR - Diversity of crop rotation; PR - Persistence of crop residues; FP - Frequency of soil tillage; TE - Use of agricultural terraces; FE - Balance of soil fertilization; TA - Time of adoption of no-tillage system

Table 4. Descriptive statistics of IQP2 and its indicators

	IR	DR	PR	FP	TE	CA	FE	TA	IQP2
Minimum	0.667	0.000	0.000	0.000	0.000	0.175	0.000	0.000	3.317
Mean	0.867	0.590	0.554	0.631	0.710	0.694	0.590	0.672	6.629
Median	0.833	0.667	0.500	0.800	0.500	0.750	0.750	0.720	6.795
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	9.000

IR - Intensity of crop rotation; DR - Diversity of crop rotation; PR - Persistence of crop residues; FP - Frequency of soil tillage; TE - Use of agricultural terraces; CA - Evaluation of soil conservation; FE - Balance of soil fertilization; TA - Time of adoption of no-tillage system; IPQ2 - No-tillage system participatory quality index

Table 6. Mean and standard deviation (in parentheses) of the groups formed in the cluster analysis, with respect to IQP2 and its indicators

Clusters	IR	DR	PR	FP	TE	CA	FE	TA	IQP2
1	0.877	0.375	0.934	0.695	0.500	0.663	0.580	0.640	6.709
	(0.131)	(0.109)	(0.154)	(0.408)	(0.387)	(0.199)	(0.196)	(0.184)	(0.915)
2	0.870	0.656	0.600	0.925	0.858	0.727	0.639	0.830	7.626
	(0.085)	(0.052)	(0.161)	(0.161)	(0.223)	(0.194)	(0.196)	(0.180)	(0.550)
3	0.849	0.669	0.515	0.420	0.557	0.656	0.780	0.458	6.128
	(0.087)	(0.040)	(0.223)	(0.364)	(0.271)	(0.186)	(0.154)	(0.206)	(0.480)
4	0.833	0.670	0.047	0.257	0.857	0.704	0.536	0.771	5.577
	(0.097)	(0.000)	(0.125)	(0.267)	(0.244)	(0.313)	(0.173)	(0.186)	(0.705)
5	0.911	0.483	0.526	0.291	0.616	0.699	0.336	0.483	5.455
	(0.091)	(0.162)	(0.260)	(0.387)	(0.320)	(0.222)	(0.199)	(0.252)	(0.895)

IR - Intensity of crop rotation; DR - Diversity of crop rotation; PR - Persistence of crop residues; FP - Frequency of soil tillage; TE - Use of agricultural terraces; CA - Evaluation of soil conservation; FE - Balance of soil fertilization; TA - Time of adoption of no-tillage system; IQP2 - No-tillage system participatory quality index

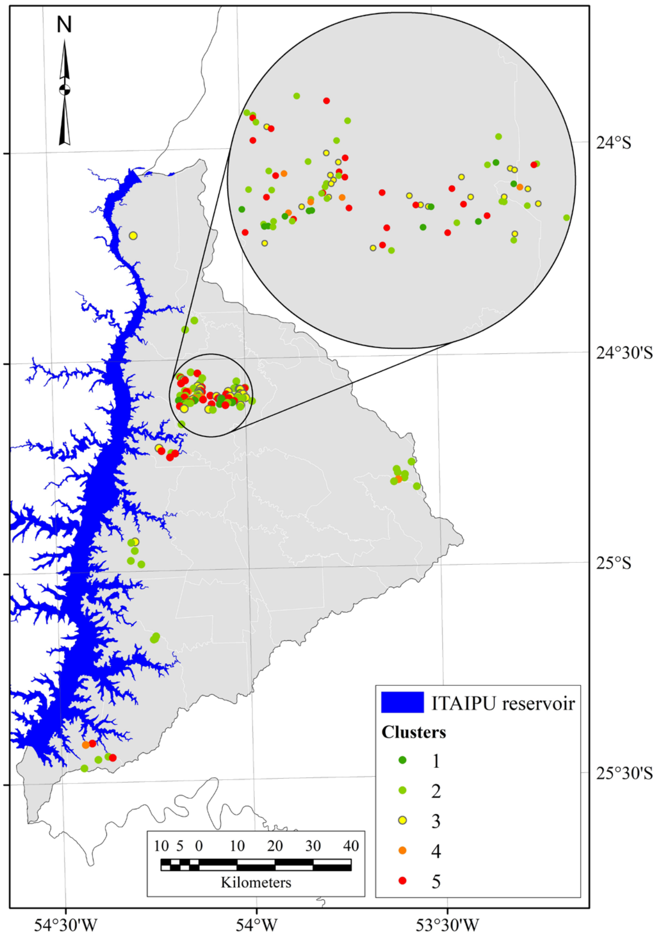

Figure 1. BP3 map with 121 farmers divided according to cluster analysis

of chemical and physical soil property analyses (Freitas et al., 2012; Perusi & Al Zaher, 2012), but those indices require soil samples and laboratory analyses and thus are very costly. Therefore, one of the advantages of the IQP2 score is that, compared with the aforementioned indices, it is more effective and less expensive while still enabling the evaluation of NTS quality.

In addition to providing information on the quality of the NTS, the IQP2 score provides information on the strengths to be maintained and on the weaknesses that need to be improved. Thus these result ultimately help in the development of an improvement plan to be implemented by the farmers seeking to improve the quality of NTS and the sustainability of the production system.

Conclusions

1. The intensity of crop rotation (IR) and the evaluation of soil conservation (CA) indicators should be reviewed since they are weakly correlated with the no-tillage system participatory quality index (IQP2).

2. The IQP2 was efficient in evaluating the quality of the no-tillage system used by the farmers, without the weakly correlated indicators.

3. Given the identification of two indicators that have a weak correlation with the IQP2, a reformulation of the index becomes necessary; this reformulation seeks to obtain eight indicators with a moderate correlation with IQP2.

4. The evaluated farmers showed heterogeneity regarding the quality of their no-tillage system (NTS), with farmers with very good NTS quality and farmers with low NTS quality being identified.

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Literature Cited

Brown, B.; Nuberg, I.; Llewellyn, R. Negative evaluation of conservation agriculture: Perspectives from African smallholder farmers. International Journal of Agricultural Sustainability, v.15, p.467-481, 2017. https://doi.org/10.1080/14735903.2017.1336051

Calegari, A.; Araújo, A. G.; Costa, A.; Fuentes-Lanillo, R.; Casão Junior, R.; Santos, D. R. Conservation agriculture in Brazil. In: Jat, R. A.; Sahrawat, K. L.; Kassam, A. H. (eds.). Conservation agriculture: Global prospects and challenges. Wallingford: CAB International, 2014. Chap.3, p.54-88. https://doi.org/10.1079/9781780642598.0054

Casão Junior, R.; Siqueira, R.; Ramchandra, Y. M.; Passini, J. J. Sistema plantio direto com qualidade. Londrina: IAPAR/ Foz do Iguaçu: ITAIPU Binacional, 2006. 200p.

Denardin, J. E.; Kochhann, R. A.; Faganello, A.; Sattler, A.; Manhago, D. D. "Vertical mulching" como prática conservacionista para manejo de enxurrada em sistema plantio direto. Revista Brasileira de Ciência do Solo, v.32, p.2847-2852, 2008. https://doi.org/10.1590/S0100-06832008000700031

Derpsch, R.; Franzluebbers, A. J.; Duiker, S. W.; Reicosky, D. C.; Koeller, K.; Friedrich, T.; Sturny, W. G.; Sá, J. C. M.; Weiss, K. Why do we need to standardize no-tillage research. Soil & Tillage Research, v.137, p.16-22, 2014. https://doi.org/10.1016/j.still.2013.10.002

Didoné, E. J.; Minella, J. P. G.; Evrard, O. Measuring and modelling soil erosion and sediment yields in a large cultivated catchment under no-till of Southern Brazil. Soil & Tillage Research, v.174, p.24-33, 2017. https://doi.org/10.1016/j.still.2017.05.011

Didoné, E. J.; Minella, J. P. G.; Reichert, J. M.; Merten, G. H.; Dalbianco, L.; Barros, C. A. P.; Ramon, R. Impact of no-tillage agricultural systems on sediment yield in two large catchments in Southern Brazil. Journal of Soils and Sediments, v.14, p.1287-1297, 2014. https://doi.org/10.1007/s11368-013-0844-6

Dougill, A. J.; Whitfield, S.; Stringer, L. C.; Vincent, K.; Wood, B. T.; Chinseu, E. L.; Steward, P.; Mkwambisi, D. D. Mainstreaming conservation agriculture in Malawi: Knowledge gaps and institutional barriers. Journal of Environmental Management, v.195, p.25-34, 2017. https://doi.org/10.1016/j.jenvman.2016.09.076

Freitas, D. A. F.; Silva, M. L. N.; Cardoso, E. L.; Curi, N. Índices de qualidade do solo sob diferentes sistemas de uso e manejo florestal e cerrado nativo adjacente. Revista Ciência Agronômica, v.43, p.417-428, 2012. https://doi.org/10.1590/S1806-66902012000300002

Friedrich, T.; Derpsch, R.; Kassam, A. Overview of the global spread of conservation agriculture. Field Actions Science Reports, v.6, p.1-7, 2012.

Fuentes-Llanillo, R.; Grossi, M. E. del; Santos, F. O.; Munhos, P. D.; Guimarães, M. F. Regionalização da agricultura do estado do Paraná. Ciência Rural, v.36, p.120-127, 2006. https://doi.org/10.1590/S0103-84782006000100018

Kaiser, H. F. The varimax criterion for analytic rotation in factoranalysis. Psychometrika, v.23, p.187-200, 1958. https://doi.org/10.1007/BF02289233

Kassam, A.; Friedrich, T.; Shaxson, F.; Pretty, J. The spread of conservation agriculture: Justification, sustainability, and uptake. International Journal of Agricultural Sustainability, v.7, p.292-320, 2009. https://doi.org/10.3763/ijas.2009.0477

Laurent, F.; Leturcq, G.; Mello, I.; Corbonnois, J.; Verdum, R. La diffusion du semis direct au Brésil, diversité des pratiques et logiques territoriales: l'exemple de la région d'Itaipu au Paraná. Confins, v.12, p.1-20, 2011. https://doi.org/10.4000/confins.7143

Lima, F. J. L.; Amanajás, J. C.; Guedes, R. V. S.; Silva, E. M. Análises de componentes principais e de agrupamento para estudo de ventos para a geração de energia eólica na região do Ceará, Paraíba, Pernambuco e Rio Grande do Norte, Brasil. Ambi-Agua, v.5, p.188-201, 2010. https://doi.org/10.4136/ambi-agua.147

Londero, A. L.; Minella, J. P. G.; Deuschle, D.; Schneider, F. J. A.; Boeni, M.; Merten, G. H. Impact of broad-based terraces on water and sediment losses in no-till (paired zero-order) catchments in Southern Brazil. Journal of Soils and Sediments, v.18, p.1159-1175, 2018. https://doi.org/10.1007/s11368-017-1894-y

Maack, R. Geografia física do estado do Paraná. Rio de Janeiro: Livraria José Olympio, 1981. 442p.

Motter, P.; Almeida, H. G. Plantio direto: A tecnologia que revolucionou a agricultura brasileira. Foz do Iguaçu: Parque Itaipu, 2015. 144p.

Nakamura, L. R.; Savian, T. V.; Dias, C. T. S.; Pinto, L. R. M.; Mazzini, A. R. A. Métodos multivariados para agrupamento de bovinos Hereford em função de suas curvas de crescimento. Revista Brasileira de Biometria, v.31, p.104-115, 2013.

Nunes, A. L. P. Estratégias para qualificação do sistema plantio direto em glebas do Oeste do Estado do Paraná. Londrina: Universidade Estadual de Londrina, 2017. 105p. Dissertação Mestrado

Perusi, M. C.; Al Zaher, C. Preparo conservacionista do solo no contexto da agricultura familiar, estudo de caso na microbacia do Córrego Fundo, município de Ourinhos/SP. Geociências, v.31, p.638-649, 2012.

Roloff, G.; Ramiro, A. T.; Mello, I. Índice de qualidade participativo do plantio direto. Ponta Grossa: FEBRAPDP, 2011. 5p. Boletim Técnico, 2011

Silva, R. L.; Maria, I. C. de. Erosão em sistema plantio direto: Influência do comprimento de rampa e da direção de semeadura. Revista Brasileira de Engenharia Agrícola e Ambiental, v.15, p.554-561, 2011. https://doi.org/10.1590/S1415-43662011000600003

Telles, T.S.; Lourenço, M.A.P.; Oliveira, J.F.; Costa, G.V.; Barbosa, G.M.C. Soil conservation practices in a watershed in Southern Brazil. Anais da Academia Brasileira de Ciências, v.91, p.1-10, 2019. https://doi.org/10.1590/0001-3765201920180578

Ward, P. S.; Bell, A. R.; Droppelmann, K.; Benton, T. Early adoption of conservation agriculture practices: Understanding partial compliance in programs with multiple adoption decisions. Land Use Policy, v.70, p.27-37, 2018. https://doi.org/10.1016/j.landusepol.2017.10.001