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Risks associated with a double-cropping production system – a case study in southern Brazil

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ABSTRACT: This study assessed the risk exposure of the production system of a typical farm in southern Brazil. Five possible production systems were analyzed, combining three crops (soybeans, corn seasons and wheat) in different crop-year combinations, for example: "Summer soybeans followed by corn" and "Autumn corn followed by winter wheat". Five different production systems were created based on the intensity of land use for each of the crops. Primary data were collected from a typical farm in the producing region over eight seasons (2006/07 to 2013/14). The Monte Carlo simulation technique was used to evaluate negative Net Operating Revenue (NOR) risk. The results showed that the production system with soybean and first season corn had a higher NOR and lower risk when compared with the other four production systems, which intensified the land use in the second season. When the production system had a higher rate of corn and/or wheat, the NOR and the risk to the production system increased for the first or second crop. Both corn and wheat in the second crop increased the risk to the production system on the typical farm in Cascavel, in the state of Parana (PR).

Keywords: Monte Carlo simulation, risk analysis, farm risk

Introduction

Agricultural production is subject to considerable market risks. These risks have been exacerbated by the onward march of climate change and globalization. One of the main concerns of agricultural policy makers has been to provide support to rural producers in the area of risk management.

The contribution of this study was aimed at assessing the risks farmers are subject to by analysing production variability and market conditions, using a typical farm as the study object, that is, not only the individual crops, as is usual, but the set of activities developed at the farm. Therefore, when assessing the risks, the allocative decisions taken by the producers were considered in order to manage them.

A number of the risk assessments in different agricultural production systems, using the Monte Carlo simulation method, have been examined in papers by authors such as Ponciano et al. (2004), Arêdes et al. (2007), Melo et al. (2012) and Asci et al. (2014). It was observed that several of the published studies have, in the main, assessed the risk of the activity referencing only one crop year, neglecting the time of purchase of inputs and sale of each crop production, as well as successive crops, which impact decisions on the use of varieties, fertilizers and other inputs. A further observation is that the studies limit the risk assessment of the agricultural product, and ignore the production systems on a typical farm, that is, summer crops and second season crops, an arrangement typically found in Brazil.

Thus, our study attempted to fill this gap in order to assess the risk of different agricultural production systems on a small farm. The data are derived from primary data collected over eight seasons (2006/07 to 2013/14), provided by the Center for Advanced Studies on Applied Economics (CEPEA, 2016). The assessment focused on the five possible production systems available to the farm, combining four agricultural products (soybean, corn, second crop corn and wheat), as related to the six different forms of land use for the first and second crop. To assess the risk of the various production systems, the Monte Carlo simulation technique was used.

Materials and Methods

Data source and processing

The data used in this study were obtained from CEPEA (2016). According to the Center, the primary data were collected on a typical farm in the Cascavel region (PR), (24°57'21″ S 53°27'18″ W), 780 m above sea level, at the end of each crop year from the 2006/07 to the 2013/14 crop. The frame of reference is a typical farm in the region, with a theoretical basis for definition, characterization and location choice criterion from the scientific works of the following authors: Elliott (1928), Plaxico and Tweeten (1963), Hazell and Norton (1986), Feuz and Skold (1991) and Deblitz et al. (1998). The panel-data collection moderation was based on the material proposed by Deblitz et al. (1998). The typical farm criterion and data collection were used in the study of Osaki and Batalha (2014).

The study was carried out using the data from a typical farm in the region of Cascavel (PR), which, since the 1990's, has recorded significant changes in the production system. During that time, farmers have selected soybean and corn (summer) as the first crop

and wheat as the second crop (autumn/winter) for their agricultural areas. With the introduction of new short and medium-cycle soybean cultivars and the prevalence of direct sowing (agricultural implements, agricultural pesticides and fertility management), producers in Paraná now have an apparently lower risk alternative in the second crop when it is corn rather than wheat and, in particular, greater marketing liquidity, which may result in higherNOR.

According to CEPEA (2016), the data used in this work were obtained through primary surveys conducted during the second and third quarter from 2007 to 2014. The size of the typical farm in the region of Cascavel (PR) was 65 hectares, with the area sown with soybean in summer and the second crop with corn and wheat. These activities are carried out by three tractors and a grain harvester. The employees consist of two tractor drivers, a temporary worker (seasonal worker) and two family members. The physical structure was the same for the eight seasons assessed (2006/07 to 2013/14) and the average monetary values of each crop were adjusted with reference to the IGP-DI (General Price Index – Internal Availability), using Dec 2014 as a base (IPEA, 2015).

The primary data collected over eight seasons were treated statistically, defining the probability function and generating 5,000 interactions for each of the main items that comprise the operating cost consisting of: fertilizers, treated seeds, herbicides, insecticides, fungicides, other inputs (adjuvants and spreader-stickers), mechanical operation, outsourced services, manual labor, general farm and miscellaneous expenses (sales tax, technical support, insurance and interest on working capital), yield, price to arrive at net operating revenues.

The crops available at the farm generate five different production systems. As the land-use intensity changes every crop year, the farm`s cost and income effects were simulated at six different land-use intensities in the first and second crop (Table 1). Production System 1 (System 1) consists of the combination of soybean and corn in the first crop with no second crop cultivated. The system begins with soybean cultivation in 100 % of the area, followed by the combination of 80 % soybean and 20 % corn; 60 % and 40 %; 40 % and 60 %; 20 % and 80 % and ends with 100 % corn.

Keeping the same land-use systematization of System 1, which only considered first crop cultivations (summer), the other four systems were structured so as to analyze the inclusion of the second crop with only corn, then only wheat and finally, with both crops. System 2 analyzed the distribution of the second crop between corn and wheat; System 3 analyzed the use of corn only in the second crop, with different land-use intensity; in System 4 100 % of the area of the second crop was sown with corn; in System 5 100 % of the area of second crop was sown with wheat.

Conceptual model

Based on the technical coefficients and input purchase prices, the production operating costs for each crop were calculated in each crop year and

Table 1 – Land use for different productions systems with the combination of first and second crop in the typical farm in Cascavel.

Systems	Crop-year	Crop	Land use					
			Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
			——————————— % ———————————					
System 1	1st	Soybean	100	80	60	40	20	0
		Corn first crop	0	20	40	60	80	100
	2nd	Corn second crop	0	0	0	0	0	0
		Wheat	0	0	0	0	0	0
System 2	1st	Soybean	100	80	60	40	20	0
		Corn first crop	0	20	40	60	80	100
	2nd	Corn second crop	100	80	60	40	20	0
		Wheat	0	20	40	60	80	100
System 3	1st	Soybean	100	80	60	40	20	0
		Corn first crop	0	20	40	60	80	100
	2nd	Corn second crop	100	80	60	40	20	0
		Wheat	0	0	0	0	0	0
System 4	1st	Soybean	100	80	60	40	20	0
		Corn first crop	0	20	40	60	80	100
	2nd	Corn second crop	100	100	100	100	100	100
		Wheat	0	0	0	0	0	0
System 5	1st	Soybean	100	80	60	40	20	0
		Corn first crop	0	20	40	60	80	100
	2nd	Corn second crop	0	0	0	0	0	0
		Wheat	100	100	100	100	100	100

Source: Research data.

were then compared to Gross Revenue, which was obtained by multiplying the production volume by the price of each product. Therefore, in this study the conceptual model estimated the economic indicators founded on the climatic and economic risks of the activity in each crop year. Based on the historical evolution of each operating cost and revenue item, the distribution functions of each item were obtained. Conceptually, based on aggregate data, we have:

$$NOR_i = \sum_{i=1}^{n} GR_i - OC_i \qquad (1, ..., n)$$

Being: $NOR_i = f (NOR_i)$: Cumulative probability distribution of the net operating revenue of the ith product used in the production system; $GR_i = f (GR_i)$: Cumulative probability distribution of the gross revenue of the ith product used in the production system; $OC_i = f (OC_i)$: Cumulative probability distribution of the operating cost of the ith product used in the production system; n: number of data simulated.

The definitions of the economic indicators assessed in the study are as follows: a) Operating Cost (OC) is the sum of the amounts spent during the production process, consisting of fertilizers, treated seeds, herbicides, fungicides, other inputs (adjuvants and spreader-stickers), mechanical operations, outsourced services, manual labor, general expenses of the farm and miscellaneous, sales tax, technical assistance, insurance and interest on working capital; b) Gross Revenue (GR) is the sum of the agricultural product values negotiated by the farm during the season under assessment; c) Net Operating Revenue (NOR) is the difference between gross revenue and operating cost.

Monte Carlo Method

The Monte Carlo method was originally developed by Hertz (1964) and later by financial experts. The process consists of defining the relative frequency of occurrence of a certain phenomenon under analysis, defining the distribution function that best suits the relative frequency, and randomly repeating the experiment several times within the established limits (Hertz, 1964). Thus, the objective of the Monte Carlo method is to determine alternative economic situations by projecting values which are random but within the limit imposed by the distribution of the variables (Hertz, 1964).

Noronha (1987) suggests a sequence of calculations to conduct the Monte Carlo simulation:

I. Identify the probability distribution of each of the variables relevant to the study;

II. Randomly select a value for each variable from its probability distribution;

III. Calculate the value of the selected indicator each time the random drawing is made as indicated in item II;

IV. Repeat the process until an appropriate confirmation of the frequency distribution of the selected indicator is obtained. This distribution will serve as the basis for decision-making.

The Monte Carlo method is simple and is often utilized in many research studies. However, two problems should be emphasized. The first refers to the definition stage of the probability distribution, and the second to the acquisition of random values.

The first problem focuses on the difficulty of determining algebraically the distribution function of the items of greatest relevance in the scope of the study. Therefore, so as to circumnavigate the problem, many studies treat the price distributions as a *proxy*, as in the case of a normal distribution, which is based on the large numbers theorem. Studies such as Ponciano et al. (2004), assumed a triangular distribution, with the functions defined by the most probable average level or modal, minimum and maximum level, which is important when insufficient prior knowledge is available about the variables. The second problem was that, even though the numbers are generated randomly in the predetermined distribution limit, the difficulty lies in finding the interdependence relationship between the variables, since the covariance of certain of the products is not zero.

For Blank and Tarquin (2012), the Monte Carlo simulation was regarded as a substitute method of a study of a non-stochastic process by a probabilistic model. In this context, the deterministic problems can be assessed by a series of random samplings.

Specifically in this study, the following variables were considered as risk factors in the production cost: fertilizers, treated seeds, herbicides, insecticides, fungicides, other inputs (adjuvants and spreader-stickers), mechanical operation, outsourced services, manual labor, general and miscellaneous expenses of the farm (sales tax, technical assistance, insurance and interest on working capital), yield, price and net operating revenues.

Based on the frequency distribution of the original data, the model calculates mean and standard deviation and analyzes, for each item in the production, cost structure and revenue, and the frequency distribution that best fits. This selection is made based on the Akaike test. From the choice of distribution, the model generates 5,000 random observations, as per the Monte Carlo simulation. In the generation of random numbers, the correlation matrix between the variables with distribution functions was structured, that is, for each variable in the crops, subjected to analysis.

Next, using the Monte Carlo Method, 5,000 random interactions were simulated for each variable of each production system. All risk analysis procedures were carried out using the @risk software program, version 6. The outputs in Operating Cost (OC), Gross Revenue (GR) and Net Operating Revenue (NOR) were also generated in these interactions.

Results and Discussion

The results discussed in this section can be divided into two subsections. The first subsection organized the statistical description of the data series used in the study. The second exhibits the risks in the production systems of the typical farm.

Descriptive statistics of the economic indicators

Table 2 illustrates the estimated frequency distribution functions for the risk variables that comprise the production cost and gross revenue of the typical farm in Cascavel (PR). The production cost is arranged by fertilizer, treated seeds, herbicides, insecticides, fungicides, others inputs, mechanical operation, service, labor cost,

Table 2 – Probability distribution of each variable which determined production cost and gross revenue of the typical farm in Cascavel (PR), 5000 random data, in US$ ha⁻¹.

Variable	Distribution	Average	Mode	Median	SD	CV
Soybean						
						%
Fertilizer	Extreme value	148.86	132.61	142.93	36.11	24.25
Seeds treated	Extreme value	83.40	76.81	80.99	14.63	17.55
Herbicides	Normal	42.23	41.82	42.01	17.04	40.34
Insecticides	Extreme value	37.22	32.67	35.56	10.11	27.18
Fungicides	Normal	49.28	49.28	49.28	7.52	15.26
Others inputs	Minimum extreme value	15.93	18.39	16.60	6.10	38.27
Mechanical Operation	Minimum extreme value	90.80	101.36	94.44	23.46	25.84
Service	Extreme value	31.75	24.88	29.24	15.24	47.99
Labor cost	Extreme value	60.20	47.97	55.74	27.15	45.10
Farm overhead	Extreme value	42.44	35.38	39.86	15.69	36.97
Other (miscellaneous)	Extreme value	88.01	92.02	89.47	8.90	10.11
Yield (t ha⁻¹)	Minimum extreme value	1.20	1.28	1.23	0.18	15.36
Price (US$ t⁻¹)	Minimum extreme value	354.53	372.94	361.01	40.93	11.54
Gross Revenue	Output	1067.05	1119.84	1088.93	199.95	18.74
Operating Cost	Output	690.13	690.18	688.53	51.04	7.40
Net Operating Revenue	Output	376.93	531.48	402.27	192.03	50.95
Prob. NOR < 0	4.0 %					
Corn first crop						
Fertilizer	Extreme value	332.19	307.02	321.65	64.13	19.30
Seeds treated	Minimum extreme value	203.59	219.21	210.37	41.94	20.60
Herbicides	Minimum extreme value	42.58	45.44	43.71	6.92	16.24
Insecticides	Normal	17.99	17.25	17.78	8.10	45.02
Fungicides	Normal	16.58	13.55	15.90	9.25	55.78
Other inputs	Extreme value	6.15	4.07	5.23	5.61	91.20
Mechanical Operation	Minimum extreme value	95.28	102.60	98.82	22.31	23.41
Service	Extreme value	92.51	78.05	87.05	33.26	35.96
Labor cost	Minimum extreme value	57.63	67.08	60.13	20.79	36.08
Farm overhead	Extreme value	42.44	35.29	39.86	15.69	36.97
Other (miscellaneous)	Minimum extreme value	109.49	113.21	110.89	8.55	7.81
Yield (t ha⁻¹)	Minimum extreme value	3.73	3.88	3.79	0.40	10.69
Price (US$ t⁻¹)	Normal	157.79	157.53	157.79	20.90	13.24
Gross Revenue	Output	1482.53	1518.83	1486.30	264.57	17.85
Operating Cost	Output	1016.42	985.49	1016.07	81.35	8.00
Net Operating Revenue	Output	466.11	543.05	471.04	299.52	64.26
Prob. NOR < 0	6.3 %					
Corn second crop						
Fertilizer	Minimum extreme value	208.01	232.24	216.35	53.81	25.87
Seeds treated	Minimum extreme value	166.28	185.03	172.79	41.60	25.02
Herbicides	Normal	33.61	33.60	33.60	9.78	29.10
Insecticides	Normal	20.50	20.50	20.50	5.83	28.46
Fungicides	Minimum extreme value	21.56	24.78	22.50	7.65	35.47
Other inputs	Extreme value	1.09	0.44	0.90	0.87	79.78

Continue...

Table 2 – Continuation.

Mechanical Operation	Minimum extreme value	83.48	93.16	86.81	21.49	25.75
Service	Extreme value	54.04	47.83	51.77	13.80	25.54
Labor cost	Minimum extreme value	48.68	55.84	50.83	16.71	34.32
Farm overhead	Extreme value	42.44	35.38	39.86	15.69	36.96
Other (miscellaneous)	Minimum extreme value	74.11	78.65	75.77	10.08	13.60
Yield (t ha⁻¹)	Normal	1.90	1.91	1.90	0.26	13.80
Price (US$ t⁻¹)	Extreme value	151.07	138.33	146.42	28.32	18.74
Gross Revenue	Output	719.16	671.23	701.10	149.65	20.81
Operating Cost	Output	753.82	781.07	757.62	95.26	12.64
Net Operating Revenue	Output	-34.65	-96.40	-53.58	164.52	-474.78
Prob. NOR < 0		63.10 %				

Wheat						
Variable	Distribution	Average	Mode	Median	SD	CV
						%
Fertilizer	Extreme value	164.79	154.16	161.13	22.30	13.53
Seeds treated	Normal	104.22	102.13	104.22	23.78	22.82
Herbicides	Normal	29.98	30.30	29.85	11.80	39.36
Insecticides	Minimum extreme value	10.93	12.43	11.40	3.95	36.11
Fungicides	Minimum extreme value	30.58	34.19	31.92	10.77	35.21
Other inputs	Normal	2.85	2.94	2.83	1.21	42.53
Mechanical Operation	Normal	63.66	64.93	63.20	26.86	42.20
Service	Extreme value	20.40	15.41	18.82	9.59	47.02
Labor cost	Minimum extreme value	41.80	46.99	43.61	12.52	29.96
Farm overhead	Extreme value	42.44	36.28	39.86	15.68	36.95
Other (miscellaneous)	Extreme value	51.65	47.56	50.11	9.42	18.23
Yield (t ha⁻¹)	Extreme value	0.85	0.76	0.82	0.22	26.28
Price (US$ t⁻¹)	Extreme value	228.00	199.53	217.24	65.46	28.71
Gross Revenue	Output	480.68	464.83	456.28	158.78	33.03
Operating Cost	Output	563.31	560.75	560.16	61.49	10.92
Net Operating Revenue	Output	-82.63	-176.14	-102.87	121.40	-146.92
Prob. NOR < 0		80.0 %				

The exchange rate used to convert the Brazilian currency to the US currency was 2.516 R$/US$, which represents the average value adjusted by the IGP-di deflator, Dec/14 = 100, between the crop year 2006/07 and 2013/14; SD = Standard deviation; CV = Coefficient of variation and NOR = Net Operating Revenue; Source: Research data.

farm overhead and other miscellaneous items. As for gross revenue it was determined by the yield and the price of the three crops found on the typical Cascavel farm. It also shows the average, mode, median, standard deviation and coefficient of variation for each variable after 5,000 random interactions, in terms of the mean value of eight seasons (2006/07 to 2013/14) adjusted data for Dec/2014.

Generally, the same distribution functions prevailed in the crops analyzed. For the same production cost item, equality of distribution was also commonly observed, regardless of the crop analyzed. The functions identified were: Extreme Value, Minimum Extreme and Normal Value.

In Table 2, the average NOR of soybean was US$ 376.9 ha⁻¹ and prob. NOR < 0 was 4 %. The first corn crop had an average NOR of US$ 466.1 ha⁻¹ and the prob. NOR < 0 was 6 %; the second corn crop had a negative NOR of US$ 34.6 ha⁻¹ and prob. NOR < 0 was 63 % and for wheat the negative NOR was US$ 82.6 ha⁻¹ and prob. NOR < 0 was 80 %.

Interestingly, the different factors that make up the cost of production and the gross revenue also influence the variation in profitability of the production system of a typical farm. Thus, sensitivity analysis helps to identify the critical variables that may be the risk factor in the agricultural production of soybeans, corn and wheat.

Next, using as a reference the productive systems of the typical farm described in Table 1, the costs and revenues of the productive systems were calculated in terms of output. The subtraction of the Operating Cost from Gross Revenue generated the NOR of each system, which also randomly generated the 5,000 interactions. Table 3 illustrates the descriptive statistical information of the NOR of each system, according to the proposed land use. In general, the high coefficient of variation (CV) values show the expressive dispersion of the NOR in the systems analyzed. Further details of the negative NOR risks are presented in the following section.

Table 3 – Frequency distribution of Net Operating Revenue (NOR) of five productions systems simulated on a typical farm in Cascavel (PR), with different land-use intensities, in US\$ ha^{-1} or percentage.

		System 1 (no double-crop)					
	1st Crop (S - M1)	100 - 0	80 - 20	60 - 40	40 - 60	20 - 80	0 - 100
	2nd Crop (M2 - W)	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0
GR	Average	1067.05	1150.15	1233.24	1316.34	1399.44	1482.53
OC	Average	690.13	755.38	820.64	885.90	951.16	1016.42
NOR	Minimum	-666.55	-563.01	-459.47	-355.93	-616.15	-877.45
	Maximum	848.03	859.29	931.85	1121.66	1311.47	1561.17
	Average	376.93	394.76	412.60	430.44	448.27	466.11
	Standard deviation	191.99	163.93	164.81	194.25	242.04	299.52
	Variance	92742.13	67609.74	68340.22	94933.62	147389.86	225709.02
	Mode	447.21	419.47	403.16	457.14	417.76	543.05
	CV (%)	50.94	41.53	39.94	45.13	53.99	64.26
	Prob. NOR < 0 (%)	4.00	2.10	1.40	1.80	3.50	6.30
		System 2 (second corn and wheat 0 - 100)					
	1st Crop (S - M1)	100 - 0	80 - 20	60 - 40	40 - 60	20 - 80	0 - 100
	2nd Crop (M2 - W)	100 - 0	80 - 20	60 - 40	40 - 60	20 - 80	0 - 100
GR	Average	1786.22	1821.62	1857.01	1892.41	1927.81	1963.21
OC	Average	1443.94	1471.10	1498.26	1525.42	1552.57	1579.73
NOR	Minimum	-785.21	-614.22	-450.83	-440.24	-746.51	-1052.77
	Maximum	1518.01	1264.09	1165.49	1349.64	1533.79	1717.94
	Average	342.28	350.52	358.76	367.00	375.24	383.48
	Standard deviation	251.39	211.63	199.45	219.50	264.55	324.34
	Variance	159008.15	112680.92	100084.38	121218.52	176083.39	264678.93
	Mode	296.32	339.04	430.68	348.61	313.69	411.34
	CV (%)	73.45	60.38	55.59	59.81	70.50	84.58
	Prob. NOR < 0 (%)	8.40	5.10	3.70	4.80	7.60	11.90
		System 3 (Second corn 0-100)					
	1st Crop (S - M1)	100 - 0	80 - 20	60 - 40	40 - 60	20 - 80	0 - 100
	2nd Crop (M2 - W)	100 - 0	80 - 0	60 - 0	40 - 0	20 - 0	0 - 0
GR	Average	1786.22	1725.48	1664.74	1604.01	1543.27	1482.53
OC	Average	1443.94	1358.44	1272.93	1187.43	1101.93	1016.42
NOR	Minimum	-785.21	-577.31	-369.40	-335.05	-606.25	-877.45
	Maximum	1518.01	1287.65	1194.69	1119.70	1310.49	1561.17
	Average	342.28	367.04	391.81	416.58	441.34	466.11
	Standard deviation	251.39	210.24	193.27	206.53	245.17	299.52
	Variance	159008.15	111207.27	93976.95	107317.09	151227.82	225709.02
	Mode	296.32	338.27	362.77	447.94	509.65	543.05
	CV (%)	73.45	57.28	49.33	49.58	55.55	64.26
	Prob. NOR < 0 (%)	8.40	4.40	2.70	2.50	4.00	6.30
		System 4 (100 % second corn)					
	1st Crop (S - M1)	100 - 0	80 - 20	60 - 40	40 - 60	20 - 80	0 - 100
	2nd Crop (M2 - W)	100 - 0	100 - 0	100 - 0	100 - 0	100 - 0	100 - 0
GR	Average	1786.22	1869.31	1952.41	2035.50	2118.60	2201.70
OC	Average	990.07	1092.49	1186.67	1224.21	1237.19	1250.18
NOR	Minimum	-785.21	-637.79	-490.36	-457.41	-566.64	-827.93
	Maximum	1518.01	1444.09	1417.25	1440.71	1464.17	1553.71
	Average	342.28	360.11	377.95	395.79	413.62	431.46
	Standard deviation	251.39	232.26	234.46	257.44	296.41	346.01
	Variance	159008.15	135726.23	138307.23	166751.11	221057.87	301227.46
	Mode	296.32	322.43	324.29	366.16	479.72	520.61
	CV (%)	73.45	64.50	62.03	65.05	71.66	80.20
	Prob. NOR< 0 (%)	8.40	6.00	4.90	5.70	8.10	10.40

Table 3 – Continuation.

		System 5 (100 % Wheat)					
	1st Crop (S - M1)	100 - 0	80 - 20	60 - 40	40 - 60	20 - 80	0 - 100
	2nd Crop (M2 - W)	0 - 100	0 - 100	0 - 100	0 - 100	0 - 100	0 - 100
GR	Average	1547.73	1630.83	1713.92	1797.02	1880.11	1963.21
OC	Average	1253.44	1318.69	1383.95	1449.21	1514.47	1579.73
NOR	Minimum	-880.38	-776.84	-673.30	-569.76	-791.48	-1052.77
	Maximum	1177.83	1285.85	1393.88	1501.90	1609.92	1717.94
	Average	294.29	312.13	329.97	347.80	365.64	383.48
	Standard deviation	225.26	202.67	204.18	229.30	271.57	324.34
	Variance	127671.50	103347.22	104885.81	132287.32	185551.67	264678.93
	Mode	396.78	353.74	375.04	319.49	327.17	411.34
	CV (%)	76.54	64.93	61.88	65.93	74.27	84.58
	Prob. NOR < 0 (%)	9.30	6.00	5.00	6.00	8.80	11.90

S = Soybean; M1 = Corn first crop; M2 = Corn second crop; W = Wheat; GR = Gross Revenue; OC = Operating Cost; NOR = Net Operating Revenue; CV = Coefficient of variation; Source: Research data.

Risk of the production system on a typical farm in Cascavel (PR)

In this section, the results of the economic analysis, including risk, of the five production systems with different land use intensities are presented for the typical farm in Cascavel (PR), according to Figure 1. System 1, which cultivates soybean and summer corn and has no double-crop, showed the highest return and lowest negative net operating return in the representative production systems of the typical farm. The cultivation of the entire area with soybean showed a probability of 4 % of presenting negative NOR. In this case, the agricultural area planted with 80 % soybean and 20 % with corn in the summer period has the potential to register a negative return of 2 %. However, as the area sown with corn after soybean increases in System 1, the return and the risk also increase (Figure 1). Dividing the agricultural area into 60 % soybean and 40 % corn in the first crop, a negative return risk of 1 % and average net revenue of US$ 412.6 ha^{-1} was identified. When the ratio of the soybean area in the agricultural area was reversed to 40 % soybean and 60 % corn, the negative return risk increases to 2 % and the mean operating return is US$ 430.4 ha–1. With a composition of 80 % corn and 20 % soybean in the agricultural area in the first crop, the risk of this activity showing a negative result is 3 % and the average operating return US$ 448.3 ha^{-1}. The maximum risk in the summer cultivation arises when 100 % of the area is planted with corn, which generates an average return of US$ 466.1 ha^{-1} and the risk of a negative return rises to an estimated 6 %.

By analyzing individually, the two crops frequently grown in the first crop in Cascavel (PR), it is noted that corn presents a higher risk than soybean. The result was contrary to that observed by Melo et al. (2012), who diagnosed greater variability in the net revenue of soybean (higher variance and standard deviation) when compared to corn.
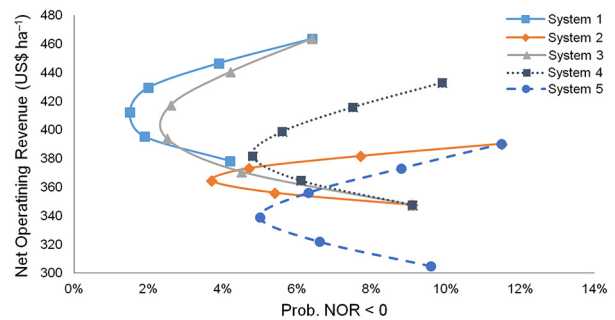

Figure 1 – Economic return (NOR) and probability of a negative return of five production systems of the typical farm in Cascavel (PR), US$ ha^{-1}. System 1 (S1): soybean and first corn (0 – 100 %); System 2: (S1) + second corn and wheat (0 – 100 %); System 3: (S1) + second corn (0 – 100); System 4: (S1) + second corn (100 %); and System 5: (S1) + wheat (100 %); Source: Research data.

The result shown in Table 3 indicates that corn provides a greater risk to the farm's activity than soybean (higher variance and standard deviation). From the agronomic point of view, corn is more sensitive to thermal variation than soybean. The thermal elevation for each vegetative phase of the crop provokes a different productivity response. In general, corn is more sensitive to nocturnal temperature than soybean, because a small thermal difference between daytime and nighttime temperature causes the plant to continue to release energy during the respiration process. Lobell and Field (2007) *apud* Hatfield et al. (2011) found that a temperature increase of 1 °C reduces the productivity of corn by 8 %, and of soybean by only 1 %.

Out of the systems analyzed, combining different forms of occupation of the agricultural area for the second crop, System 3 had the highest return and the lowest probability of a negative return. System 5 had the worst economic performance (Figure 1).

In System 3, the choice of sowing the agricultural area with 100 % soybean in the summer and the entire area with corn in the second crop showed an 8 % chance of presenting a negative return. Moreover, with a combination of 80 % of the agricultural area sown with soybean and 20 % with corn in the summer crop, with 80 % corn in the second crop, the risk of a negative return reduces to 4 %. In the composition of the agricultural area with 60 % soybean and 40 % corn in the summer crop and 60 % corn in the second crop, the chance of a negative return for the farm decreases to 3 %. As the corn proportion increases in the agricultural area in the summer crop, the profitability of the farm and the negative return risk move up. When the corn crop occupies 60 % of the agricultural area is sown with corn and the remainder with soybean, and then 40 % of the area is sown with corn in the second crop, the risk of a negative return is 2 %. In the combination of 80 % with corn and 20 % with soybean in the first crop and only 20 % with corn in the second crop, the result showed that the risk of a negative return rises to 4 %.

In System 4 with 100 % of the agricultural area sown with corn in the second crop, and a combination of 80 % of the area sown with soybean and the remaining 20 % with corn in the summer crop, and 100 % with second crop corn the risk of registering a negative return is 6 %. Land use in the proportion of 60 % sown with soybean and 40 % with corn in summer and 100 % of corn in summer shows the probability of a negative return of 5 %. By sowing the agricultural area with more corn compared to the summer period, the risk of a negative return increases. In general, the return and the risk of the farm increase with more corn in the first crop. The difference is that the operating return of System 4 is lower than the production Systems 1 and 3, but raises risk exposure.

System 1 had superior NOR in comparison to the other four systems. When System 1 is compared to System 3 within the same combination of soybean and summer corn in first crop area, the results of System 3 were inferior. For example, comparing the same combination of 60 % soybean and 40 % summer corn, System 1 found an average NOR of US$ 412.6 ha^{-1} and Prob. NOR < 0 was 1 % (CV of 40 %) against System 3 with a NOR of US$ 391.8 ha^{-1} and Prob. NOR < 0 was 3 % (CV% 49 %). The reduction jn the NOR of System 3 was observed after the second crop had been added, which had a negative value of US$ 20.8 ha^{-1}. Increases in the share of the second corn crop in System 3, produces a decrease in the NOR and the probability of a negative result increases. In System 4, when sowing 100 % of the area with the second corn crop, the average NOR value of System 4 was US$ 34.6 ha^{-1} lower than System 1. The difference was constant for all six types of soybean and summer corn combinations (Table 3).

The presence of wheat as a second crop option was simulated in Systems 2 and 5. System 2 combines the soybean and corn crop in the summer and corn and wheat in the second crop. When 80 % of the agricultural area is sown with soybean and 20 % with corn in the summer crop and 80 % with corn and 20 % with wheat in the second crop, the risk of a negative return is 5 %. When the agricultural area was sown with 60 % soybean and 40 % corn in the first crop and subsequently, 60 % corn and 40 % wheat, the possibility of a negative return is 4 %. Furthermore, by reducing the soybean area to 40 % and expanding the corn area to 60 % in the first crop and sowing the area with 40 % corn and 60 % wheat, the negative return increases to 5 %. The land use combination of 80 % soybean and 20 % corn in the first crop, and 20 % corn and 80 % wheat, increases the possibility of a negative return to 7 %. Finally, sowing the agricultural area with 100 % corn in the first crop and 100 % wheat increases the risk of a negative return to 12 %.

In System 5, when 100 % of the agricultural areas is sown with soybean and 100 % with wheat in the second crop, the risk of a negative return is 9 %. When combining 80 % soybean and 20 % corn in the first crop and 100 % wheat in the second crop, the risk of a negative return is 6 %. In the land-use composition with 60 % soybean and 40 % corn in the first crop, the risk of a negative result is 5 %. This risk increases as the proportion of corn increases. When the agricultural area is sown with 60 % corn and 40 % soybean in the first crop and the entire area with wheat in the second crop, the risk of a negative return is 6 %. When the land use is 80 % corn and 20 % soybean in the first crop and 100 % of the area is sown with wheat in the second crop, the risk is 9 %. The combination of the entire area being sown with corn in the first crop and wheat in the second crop, implies the risk of a negative return of 12 %, as observed in System 2 (Figure 1).

In the case of System 2, the combination of second corn crop and wheat presented negative NOR and the profitability of System 2 declines as the wheat area proportion increases in the production system since the NOR of wheat is more negative than a second corn crop. System 5, in which 100 % of the area was sown with wheat in the second harvest, the average NOR value of System 5 was US$ 82.6 ha^{-1} lower than System 1 (Table 3).

In general, the results showed that the production system with soybean and corn in the first crop has a higher NOR and lower risk when compared with the other four systems, which enhances the land use with the second crop. However, when the presence of corn is increased in the first crop, at the expense of soybean, the NOR and risk also increase. The agricultural area sown with 60 % soybean and 40 % corn showed the lowest risk.

In the more intensive production system, which introduces a second crop after soybean or corn, the risk of the typical farm increases. In the four cases assessed, all recorded increased risk, but profitability did not outperform the one-crop cultivation system. This result raises questions about the producer's strategy for maximizing land use in an attempt to earn as much with the first as with the second crop.

Cultivating corn and wheat in the second crop showed that both increase risk to the production system. The most worrying situation is the presence of wheat, as it considerably lowers profitability and increases risk to the production system of the farm, as seen in Systems 2 and 5. Wheat production in Brazil is more vulnerable to climate variations and the grain quality is easily reduced, which in turn decreases the producer's remuneration. On the other hand, the presence of this crop in the system is justified by its stimulation of productivity gains in soybean and corn, since this cereal increases straw in the soil, and promotes crop rotation and chemicals to control weeds, diseases and pests.

As regards second crop corn, it was expected that its introduction into the production system would increase the profitability of the farm, but this was not observed in Systems 2, 3 and 4. It is suspected that the new genetic technology introduced in the seed and the greater use of insecticides increased the cost of production, especially in the last three years (2011/12 to 2013/14), reducing the profitability of second crop corn. Nevertheless, our study did not discriminate production by type of technology, which will be the focus of future research. Out of the four systems used in the agricultural area for two crops, System 3 showed the most promising results, particularly the composition of the agricultural application of 60 % soybean, and 40 % corn in the summer crop and 60 % corn in the second crop.

The study was limited to assessing one location, restricting any economic risk considerations posed by the five production systems to Cascavel alone. Even so, it produced results were far-reaching, given that the primary data used to portray the reality of the production system (management and technology) of each crop, were validated by local producers and consultants and obtained over a long period.

Authors' Contributions

Conceptualization: Osaki, M., Alves, L.R.A. Data acquisition: Osaki, M., Lima, F.F., Ribeiro, R.G. Data Analysis: Osaki, M., Alves, L.R.A. Design of methodology: Osaki, M., Alves, L.R.A., Barros, G.S.A.C. Software development: Osaki, M., Alves, L.R.A. Writing and Editing: Osaki, M., Alves, L.R.A., Barros, G.S.A.C.

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