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**Irrigation adoption by orange producers of the state of São Paulo-Brazil: determinants and barriers.**

Fabiana Ribeiro Rossi

*Federal University of São Carlos-Brazil, fabianarossi@dep.ufscar.br*

Hildo Meirelles de Souza Filho

*Federal University of São Carlos-Brazil, hildo@dep.ufscar.br*

Marcelo José Carrer

*Federal Institute of Education, Science and Technology of São Paulo-Brazil,  
marcelojcarrer@ifsp.edu.br*

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# **Irrigation adoption by orange producers of the state of São Paulo-Brazil: determinants and barriers.**

## **Abstract**

*Brazil is the larger producer of fresh oranges contributing with 55% of the world's production. The state of São Paulo produces more than 70% of Brazilian's national fresh oranges production. In spite of the importance of the orange activity to the economy of Brazil, more than 70% of the orange producers abandoned the activity in São Paulo between 1995 and 2014 due mainly to considerable reduction in their profits. Adopting irrigation can lead to an increase in production factor yields and, consequently, to a reduction on production costs per orange box, restoring the producers' profitability. This paper aims to identify and analyze the factors that influence the adoption of irrigation systems in orange orchards in São Paulo-Brazil by using descriptive statistics, hypothesis testing and a probit model. We identified that the number of oranges varieties grown in the property, the percentage of the total agricultural income obtained with the orange activity, the number of management tools used in the production system, the risk preference of the producer with respect to the orange commercialization, the experience of the producer in the agricultural activity and the amount of money spent with technical assistance impacted significantly the irrigation adoption.*

**Key words:** orange production, irrigation adoption, determinants, barriers

**JEL:** D22, O33, Q16

## **1. Introduction**

The decision process of moving from awareness about a new technology to its adoption can be influenced by many factors. Agricultural technology adoption is mainly motivated by the pursuit of increasing the yields of the crop. However, institutional, economics and environmental factors and characteristics of the farms, farmers and the production system can influence the decision to invest in a new technology in the production system.

The practice of irrigation presents positive results in increasing the productivity of orange orchards. This effect has been observed in production areas where rainfall is almost absent and in rainy areas where the crop can produce without supplemental water (Petillo and Castel, 2004).

By comparing field experiments with irrigated and non-irrigated treatments, many authors identified the benefits of irrigation to orange production. Barreto et al. (1976) identified an increase of 56% in the number of fruits per 'Natal' orange tree. Smajstrla and Koo (1984), Petillo and Castel (2004), and Silva et al. (2009) identified an increase of 65%, 31% and 32%, respectively, in the production of 'Valencia' oranges. Grizotto et al. (2012) identified a

significant increase in the production of 'Valencia' oranges when treated with irrigation and a technological package. Irrigating the orchards can also result in heavier and more vigorous fruits and more uniform flowering (Barreto et al., 1976; Silva et al., 1999).

In addition to the positive impacts on the crop, citrus properties of the state of São Paulo-Brazil with orange irrigated areas showed to be more profit and technically efficient compared with farms without irrigation (Carrer, 2015).

Brazil is the world's larger producer of fresh oranges contributing 55% to the production. In 2014, the state of São Paulo was responsible for 72% of the Brazilian orange production with more than 12 million tons produced (The Brazilian Institute of Geography and Statistics - IBGE, 2015). This production is mainly marketed with juice processors and more than 90% of the juice produced is exported. The remaining orange production is destined to the domestic fresh orange market (Brazilian Association of Citrus Exporters - CITRUSBR, 2013).

In spite of the importance of the orange activity to the Brazilian economy, over the past decades more than 70% of the producers abandoned the activity in São Paulo (Survey of Agricultural Production Units – LUPA, 2008; National Supply Company – CONAB, 2013) due to reduction in their profitability driven mainly by increases in the production costs associated with the low prices paid per orange box. Adopting irrigation can lead to an increase in the production factor yields and, consequently, to a reduction on the production costs per orange box. Thus, the producers' profitability can be restored, keeping them in the activity.

Although the adoption of irrigation systems increased among São Paulo's orange producers during the mid-2000s, the adoption of these technologies is still very low in the state. In 2014, only 24.6% of the orange production area in the state was under irrigation. In the orange properties, two types of irrigation systems prevail: traveling sprinkler and localized (drip or micro sprinkler). The latter is the most widespread and is used in 88% of the orange irrigated area (Brazil's Citrus Defense Fund – FUNDECITRUS, 2015).

Thus, considering the positive effects of irrigation identified in the literature (Barreto et al., 1976; Smajstrla and Koo, 1984; Silva et al., 1999; Petillo and Castel, 2004; Silva et al., 2009; Grizotto et al., 2012 and Carrer, 2015) an increase on the rate of diffusion of these technologies is desirable. Hence, is important to understand the factors that influence irrigation adoption, as well as its barriers. This paper aims to identify and analyze the determinants and the barriers of adoption of irrigation systems by orange producers of the state of São Paulo-Brazil. We identified a lack of research regarding this subject in Brazil and the results can help the formulation of public policies and private strategies for the sector.

By using a descriptive statistics and a probit model, a set of different variables was analyzed. We found that the number of oranges varieties grown in the property, the percentage of the total agricultural income obtained with the orange activity, the number of management tools used in the production system and the risk preference of the producer with respect to the orange commercialization has a significant and positive impact on irrigation adoption. In contrast, the experience of the producer in the agricultural activity and the amount of money spent with technical assistance has a significant and negative impact on irrigation adoption.

The structure of this study will be organized as follow: Section 2 will present a conceptual framework on irrigation technology adoption; Section 3 presents the methodology (dataset and the empirical specification) used; Section 4 presents the results; Section 5 discusses the results and, finally, section 6 presents the conclusion of the study.

## **2. Conceptual Framework**

### *2.1. Determinants of irrigation technology adoption*

Many factors can affect a farmer's decision to adopt a new technology in the production system. In developing countries this subject has been widely addressed because of the importance of the agriculture to the composition of household incomes.

In Florida, the age of the producer and the in-grove spatial variability presented a negative and positive impact, respectively, on the likelihood of adoption of precision farming technologies in citrus orchards (Sevier and Lee, 2004). Lapar and Ehui (2004) identified that small producers who has higher levels of education, higher incomes and access to credit are more likely to adopt dual-purpose forages in Philippines. The farmers' perception on the characteristics of the technology, the soil type of the farm and the participation in local administration impacted significantly the adoption of *Striga* resistant sorghum by small producers in Ethiopia (Wubeneh and Sanders, 2006). According to Ogada et al. (2014) the joint adoption of inorganic and improved maize varieties in Kenya is influenced by the use of manure, access to credit, distance to input markets, secure tenure, education and gender of the household head, cultivated area, drainage of the plots, and expected yields.

With respect to irrigation technologies, the literature distinguishes mainly two stages of the adoption process. The first is related to the primary adoption in which the producer did not use previously any type of irrigation. The second is related with the change of an irrigation system for another; usually more efficient in the use of water. This second stage of adoption is specially addressed in countries or regions with water resource scarcity problems and environmental degradation. This paper will focus on the primary adoption of irrigation because

it is the stage in which these technologies are in the orange production system of São Paulo. However, in order to create broader assumptions concerning the factors that influence the acceptance of irrigation in the orange farms, both literatures were considered.

According to the literature, the factors that influence irrigation adoption can be clustered in to five groups: human capital, characteristics of the farms and production system, and institutional, economic and environmental factors. In this paper we focus on the influence of the human capital (education level, experience in the agriculture, risk preference, management tools, and technical assistance) and the characteristics of the production system (size of the production, diversification of production, commercialization, and income) on irrigation adoption.

Several authors identified a positive impact of the educational level of the household head on irrigation adoption (Barse et al., 2010; Vaezi and Daran, 2012; Shahzadi, 2013; Singh et al., 2015). Barse et al. (2010) found that the high level of education of orange producers in India influenced positively the adoption of drip irrigation. According to Vaezi and Daran (2012) and Shahzadi (2013), farmers with higher educational levels in Iran are more likely to adopt pressurized irrigation systems compared with producers with lower educational levels. Singh et al. (2015) identified that as the level of education increases among Indian farmers, the likelihood of adoption of micro irrigation systems increases too.

The use of management tools in the production system is strongly related with the educational level of the producers. This implies that the greater the educational level of the producer the greater his ability to use managerial tools. Managerial skills are required for proper utilization of irrigation systems in order to obtain the incremental yield increases crucial to achieve acceptable returns on this investment (Wilson, 2001; Namara et al., 2007). Therefore, this factor can impact positively the irrigation adoption.

The experience of the producer in the agriculture activity also influences irrigation adoption. Kumar (2012) identified that the experience in farming (proxied by the age of the producer) have a positive impact on drip irrigation adoption in India. Experience improves the awareness concerning the positive effects generated by the adoption and encourages the decision towards adoption. However, according to Kiruthika (2014) the years of experience of sugarcane producers in India have a negative impact on drip irrigation adoption. Younger producers are more likely to be less risk averse than older producers and hence more likely to become adopters.

The level of risk preference<sup>1</sup> of the producer can also affect irrigation adoption. There are many types of agricultural risks faced by the producers: production, marketing, financial, human and institutional. Additionally, adopting a new technology create uncertain on the returns of the investment which makes the adoption a risk decision. In the literature there is no consensus about the impact of risk in the acceptance of a new technology. Koundouri et al. (2002) and Vaezi and Daran (2012) identified that the producers that are more risk averse are more likely to adopt water saving technologies, such as pressurized irrigation systems, specially due to safety in water supply. On the other hand, producers that are less risk averse (or risk loving) are more likely to adopt agricultural technologies, such as retaining crop residues in the farms plots in Kenya (Wainaina et al., 2014).

Receiving information by means of technical assistance impacts positively the adoption of irrigation. According to Alcon et al. (2011), in Spain, producers that receive knowledge of the technology through specialized professionals in agriculture are more likely to adopt irrigation than producers that receive information from other sources (e.g. other producers). In Brazil, orange producers who pay for technical assistance have more probability in adopting irrigation systems in orange orchards (Rossi et al., 2015).

The size of farm also exerts a positive impact on irrigation adoption. This variable can be used as proxy to the size of the production. According to Kohansal and Darani (2009), larger producers in Iran are more likely to adopt sprinkler irrigation systems. In the same direction, Shahzadi (2013) identified that producers with larger areas has more probability to adopt pressurized irrigation systems. Larger producers have adequate capital to adopt new technologies, especially technologies that involve huge initial investments, such as irrigation.

Besides the size of the production, the diversity of crops produced can also be important to the irrigation adoption process. According to He et al. (2007), diversifying the production increase the likelihood of adopting integrated technologies of supplementary irrigation in China. However, Kohansal and Darani (2009) identified that farmers who cultivate more products are less likely to adopt sprinkler irrigation than farmers with fewer products in Iran. According to the authors, this result can be related to lower production risk faced by the producers with more products leading to a low rate of adoption. On the other hand, the negative effect of the number of products on the adoption is related to the poor management of farmers.

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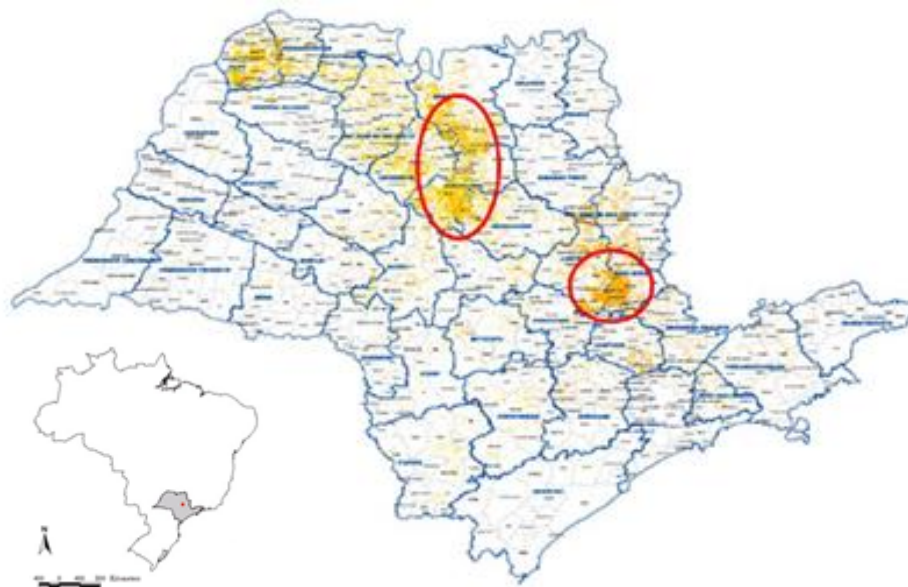
<sup>1</sup> This paper uses the risk preference concerning the sale of orange production as a proxy to the level of risk of the producer. Marketing risk occur because of variability of product prices and uncertainty on future market prices (Food and Agriculture Organization of the United Nations - FAO, 2008).

The total income is a very important factor in the irrigation adoption process. The greater the amount of money earned by non-agricultural activities the greater is the probability of adoption indicating the importance of the availability of additional capital to invest and also the ability to take some risks in the initial adoption process (Kamwamba-Mtethiwa et al., 2012; Kumar, 2012). However, according to Namara et al. (2007), the additional source of capital of the off-farm activities is only positive to adoption up to a certain level. The likelihood of adoption decreases when off-farm income becomes the main source of living. In contrast, Afrakhteh et al. (2015) found a positive impact of agriculture as the main job on the adoption of irrigation which leads to greater efforts to improve farming levels.

### 3. Methodology

#### 3.1. Dataset

The data was collected by means of a survey conducted in 2014 by the Department of Production Engineering located in the Federal University of São Carlos-Brazil<sup>2</sup>. The survey sample comprised 98 orange producers of the state of São Paulo-Brazil and is representative for the most cultivated orange areas in the state (Figure 1).



**Figure 1** – Location of the sampling region in the state of São Paulo-Brazil.

**Note:** The red circles represent the municipalities with the highest cultivated orange areas in São Paulo-Brazil.

**Source:** Souza Filho et al. (2013).

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<sup>2</sup> The survey was coordinated by Prof. Dr. Hildo Meirelles de Souza Filho (Souza Filho et al., 2013). The information obtained is confidential since it contains private information of the respondents.



From the total sample, 34 producers adopt irrigation and 64 do not adopt. The producers were interviewed using a structured questionnaire that aimed to obtain some personal information and also characteristics of the farms and the production system on the 2013/14 crop season. In the case of the non-adopters the main reasons for not irrigating the orange production was also investigated.

### 3.2. Empirical estimations

We analyzed the data using descriptive statistics (mean and standard deviation) and hypothesis testing to discriminate the group of producers who adopt irrigation systems from the group of non-adopters. A Student's t-test for independent groups was performed. Based on these analyses and on the literature review we formulated hypothesis for the possible determinants and their impacts on irrigation adoption. A probit model<sup>3</sup> was used to identify the factors that are significant in the adoption process.

Probit is a binary choice model where the dependent variable assumes the value 0 in case of non-adoption of a technology and 1 in the case of adoption. This model estimates the probability of adoption for individuals using the maximum-likelihood estimation (MLE) (Greene, 2012).

The probability of adoption can be described as:

$$\text{Prob } (Y = 1 \mid x) = F(x', \beta) \quad (1)$$

$$\text{Prob } (Y = 0 \mid x) = 1 - F(x', \beta) \quad (2)$$

where parameters  $\beta$  reflects the impact of changes in  $x$  on the probability. Probit models assume a normal distribution so the probabilities can be expressed as:

$$\text{Prob } (Y = 1 \mid x) = \int_{-\infty}^{x'\beta} \Phi(t)dt = \Phi(x'\beta) \quad (3)$$

The variables that were analyzed using descriptive statistics, hypothesis testing and a probit model were namely and described in table 1. The hypotheses of the direction of their impact on the likelihood of adoption are also presented.

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<sup>3</sup> All the data analysis was performed using Stata software version 12.

**Table 1** – Variables type and hypotheses of the impact of the variables analyzed on the likelihood of adoption of irrigation.

Variable*	Description	Type	Expected Signal of the impact on adoption
<b>VARIET</b>	N° of oranges varieties grown in property	Continuos	(+/-)**
<b>INCOCITRUS</b>	% of the total agricultural income obtained with the orange activity	Continuos	(+/-)**
<b>TECHASSIST</b>	Amount of capital expended with technical assistance	Continuos	(+)
<b>EDUC</b>	N° of years of formal education of the producer	Continuos	(+)
<b>MANAGE</b> <sup>4</sup>	N° of managerial tools used by the producers	Continuos	(+)
<b>SPOT</b>	% of the production sold using spot market to the different commercialization channels	Continuos	(-)
<b>MARKRISK</b> <sup>5</sup>	Risk preference with respect to commercialization	Continuos	(+/-)**
<b>EXPAGRIC</b>	Years of experience of the producer in the agriculture activity	Continuos	(+/-)**
<b>PROD</b>	N° of boxes of oranges produced	Continuos	(+)

**Note:** \* All the information on the variables are related to the crop season 2013/2014; \*\* There is no consensus in the literature concerning the impact of these variables in the acceptance decisions of new technologies.

**Source:** Souza Filho et al. (2013).

#### 4. Results

Table 2 presents the results obtained with the descriptive statistics and the statistical hypotheses test. Analyzing the results on Table 2 we observed that the t-test for comparison of means was statistically significant (at the 1% significance level) for the number of managerial tools used by the producers (MANAGE) and the risk preference with respect to commercialization (MARKRISK).

At the 5% significance level the t-test was statistically significant for the number of oranges varieties grown in property (VARIET), percentage of the total agricultural income obtained with the orange activity (INCOCITRUS) and the years of experience of the producer in the agricultural activity (EXPAGRIC).

<sup>4</sup> Index ranging from 0 to 7 that considers the following tools: costs control; stock control; records of the production, productivity and incidence of diseases and pests; specialized software; internet to access market information; precision agriculture techniques and agricultural production certifications.

<sup>5</sup> Index calculated according to the level of agreement with the following statement: “*I rather trust in my intuition to sale my orange production than use forward contracts*”. The Index can range from 1 to 5 in which 1 represents complete disagreement to the statement and 5 complete agreement. The greater the index, less risk averse is the producer.

At the 10% significance level the t-test was statistically significant for the number of oranges boxes produced (PROD) and the number of years of formal education of the producer (EDUC).

The average of the quantity of number of orange varieties grown, percentage of the total agricultural income obtained with the orange activity, the number of years of formal education, the number of managerial tools used, the index for the risk preference with respect to commercialization and the number of oranges boxes produced are greater for the producers who adopt irrigation systems. The years of experience of the producer in the agriculture activity is greater for the non-adopters compared with the adopters.

**Table 2** - Description of the descriptive statistics and statistical hypotheses of the variables analyzed for the two groups of orange producers.

Variables	Group 1: adopt irrigation systems 34 citrus producers		Group 2: do not adopt irrigation systems 64 citrus producers		Decision H <sub>0</sub>	
	Mean	Standard Deviation	Mean	Standard Deviation	p value	Hypothesis
VARIET	3.55	1.28	2.81	1.50	0.016	Reject**
INCOCITRUS	60.62	34.12	44.03	33.48	0.023	Reject**
TECHASSIST	5,663.68	6,135.76	4,143.11	7,112.1	0.294	Accept
EDUC	14.38	3.71	12.89	3.73	0.062	Reject***
MANAGE	3.91	1.54	2.53	1.79	0.000	Reject*
SPOT	60.74	42.15	45.72	44.21	0.107	Accept
MARKRISK	3.56	1.64	2.35	1.55	0.001	Reject*
EXPAGRIC	23.58	10.82	30.41	13.91	0.016	Reject**
PROD	80,929.02	106,240.19	46,783.43	64,921.07	0.051	Reject***

**Note:** \* p-value is statistically significant at the 1% level; \*\* p-value is statistically significant at the 5% level; \*\*\* the p-value is statistically significant at the 10% level.

**Source:** Souza Filho et al. (2013).

The Table 3 indicates the results obtained with the Probit model. This model presents a good fit for the data analyzed. The result of the likelihood ratio test (LR) - 47.94 - allows the rejection of the hypothesis in which all coefficients of the explanatory variables of the model are equal to zero. The predicted overall percentage of the model is 72.04% which can be pointed as a high prediction percentage. We did not find indications of multicollinearity based on the VIF (Variance Inflation Factor) which average of 1.53. The model was correct to heteroscedasticity and we used instrumental variables<sup>6</sup> aiming to correct an endogeneity issue.

The model showed that six of the nine explanatory variables used in the model were statistically significant. Two variables were statistically significant at the 1% level, namely: INCOCITRUS and MARKRISK; three were statistically significant at the 5% level, namely:

<sup>6</sup> The variables used to correct the endogeneity problem were: share (percentage of the orange area within the farm; another (percentage of the area with other crops in the farm) and revenue (total revenue obtained with the orange production).

VARIET, MANAGE and EXPAGRIC and one was statistically significant at the 10% level, namely TECHASSIST.

**Table 3** - Coefficients and marginal effects estimates of the probit model for the analysis of the determinants of adoption of irrigation systems by the orange producers.

Variable	Coefficient	(Robust) Standard Deviation	Marginal effects	Standard Deviation
Constant	-0.8404957	1.060931	-	-
<b>VARIET</b>	0.270498**	0.1136831	0.2657458**	0.1138835
<b>INCOCITRUS</b>	0.0162446*	0.0051951	0.0164466*	0.0049376
<b>TECHASSIST</b>	-0.0000358***	0.0000213	-0.0000351***	0.0000218
<b>EDUC</b>	-0.0424465	0.0307857	-0.0433501	0.0309425
<b>MANAGE</b>	0.2966809**	0.1189102	0.2916939**	0.1156805
<b>SPOT</b>	-0.000617	0.0031952	-0.0006709	0.0032031
<b>MARKRISK</b>	0.3187182*	0.0987805	0.3159175*	0.0979035
<b>EXPAGRIC</b>	-0.0262361**	0.0112478	-0.0263565**	0.0111609
<b>PROD</b>	8.34e-07	2.24e-06	8.37e-07	2.29e-06
Predicted Overall Percentage: 72.04%				
Likelihood ratio (LR): 47.94				

**Note:** \* statistically significant at the 1% level; \*\* statistically significant at the 5% level; \*\*\* statistically significant at the 10% level

**Source:** own elaboration.

Additionally, the table 4 presents the main reasons pointed by 64 producers of the sample for not adopting irrigation. The producers were able to report more than one reason, thus the total number of reported reasons does not match the total number of producers interviewed. We observed that the major barriers in adopting irrigation on the orchard is the high cost of the investment and the lack of availability of water close/or in the properties.

**Table 4** – Statistics of the main factors pointed out by the orange producers for non-adopting irrigation.

Factors for the non-adoption of irrigation	Statistics	
	Number	Frequency (N = 64)
High investments costs	43	67.18%
Lack of availability of water	15	23.43%
Good rainfall indices	7	10.93%
Bureaucracy to obtain environmental license	5	7.81%
Low prices paid per orange box	5	7.81%
Varieties sold only to juice processors	5	7.81%
Others*	5	7.81%

**Note:** \* Lack of qualified employees, lack of information, region without cultural traditional with irrigation, managerial complexity and land tenure.

**Source:** Souza Filho et al. (2013).

## 5. Discussion

In this section we will discuss the six determinants that were statistically significant in the econometric model. The number of varieties of oranges grown by the producer (VARIET) presented a positive impact on the adoption of irrigation. This result corroborates with He et al. (2007). The increase in one unity on the number of varieties grown will increase the likelihood of adoption in 26 percentage points. Diversifying the orange production allows the producer to sale the production during the whole year and to different market channels. Thus, the producers can obtain better prices on the product and stabilize their revenue which makes it possible to invest in the production systems.

The percentage of the total agricultural income obtained with the orange activity (INCOCITRUS) also presented a positive impact on the adoption of irrigation, corroborating with Afrakhteh et al. (2015). The increase in one unity on the percentage of income obtained producing orange increase in 1.6 percentage points the likelihood of adoption of irrigation. The greater dependence of these producers on the orange activity leads to a need of an increase of technical efficiency by the adoption of new technologies in the orchards. Irrigation, as identified by Carrer (2015), increases the technical efficiency of the orange properties.

The number of management tools used by the producer (MANAGE) also impacted positively the irrigation adoption, as hypothesized. The increase in one unity on the number of management tools used increases the likelihood of irrigation adoption in 29 percentage points. The use of administrative tools can lead to a better resource allocation in the production system allowing the adoption of new technologies. Moreover, irrigation systems require managerial skills for appropriate utilization.

A positive impact on the adoption of irrigation was also identified on the degree of risk preference with respect to commercialization (MARKRISK), corroborating with Wainaina et al. (2014). The less risk averse the producer is concerning the sale of orange the greater the probability of adopting irrigation. The increase in one unit on the index of risk preference will increase the likelihood of adoption in 31 percentage points. The producers who adopt irrigation are less risk averse in marketing their products than the non-adopters. The less use of contracts also allows the producers to differentiate the market channels and diversifying the orange production. Furthermore, less risk averse producers can accept easily new agricultural technologies and are more willing to take risks concerning its adoption.

The amount of money expended with technical assistance (TECHASSIST) showed a negative effect in the adoption of irrigation. The increase in one unit on the amount spent with assistance will decrease in 0.0035 percentage points the likelihood of irrigation adoption. This result complements the literature on adoption of technology in which receiving technical assistance affect positively the adoption of irrigation, as verified by Alcon et al. (2011) and Rossi et al. (2015). The main objective of technical assistance is to provide information in order to increase the productivity of a crop. When paying technical assistance the producer is expecting a more qualified service to fulfill this purpose, therefore the more money spent in the contract less invest will probably be done in new agricultural technologies that aim the same purpose.

Finally, the number of years of experience in the agriculture (EXPAGRIC) presented a negative impact on the adoption, as also verified by Kiruthika (2014). The increase in one unit on the years of experience will decrease in 2.6 percentage points the likelihood of adoption. Older producers are more likely to be more risk averse and hence will not accept easily new technologies compared to younger producers.

The number of years of formal education (EDUC), the number of boxes of orange produced (PROD) and the percentage of the production sold using spot market (SPOT) did not present statistically significant parameters on the adoption of irrigation.

The table 2 shows that the adopters have an orange production significantly larger than the non-adopters. This can indicate that the adopters have more capital to invest in new technologies, such as irrigation that requires a large initial investment. Similarly, the larger production allows the adopters to diversify more their commercialization channels since they are less risk averse in the sale of oranges as indicated by the variable MARKERISK. The adopters use spot market to sale 60.74% of their production while non-adopters sale 45.72% using the same mechanism as indicated by the variable SPOT. This governance structure does not create

linkages between the agents involved in the negotiation allowing more flexibility to market the orange production.

We can observe on table 4 that the main factors pointed by the producers as barriers to irrigation adoption are the high implementation costs of the systems (67.18%) and the lack of availability of water in the property and/or close (23.43%). According to the producers surveyed the implementation cost of an irrigation system can range, on average, from US\$ 1.200/ha to US\$ 1.600/ha<sup>7</sup>. In this sense, these technologies require high investment costs, as well as capital to pay for annual fixed and variables costs.

The lack of water available is also an important barrier for the producers. The farther the source of water more energy/fuel is required to transport the water capture from the source to the irrigation system. In this sense, this cost would be much higher for producers without sources of water inside the property which can make the investment unviable.

## **6. Conclusions**

The probit model showed that the adoption of irrigation is mainly impacted by the degree of risk preference of the producer with respect to the orange commercialization, followed by the number of management tools and orange varieties grown in the properties. The percentage of income obtained from the orange activity, the years of experience and the amount of money spent with technical assistance had significant but smaller impacts on the adoption.

The consolidation of the ongoing price referencing mechanism called Council of producers and exporters of Orange juice (CONSECITRUS)<sup>8</sup> would help the producers to be more confident in the market, plan more accurately the production and diversify the commercialization channels.

Technical assistance is an important mechanism to provide information about new technologies and its benefits. For some producers contracting private technical assistance is not affordable. Thus, public policies should be created and/or reformulated in order to assist more widely the producers. These services shouldn't approach only the production aspects of the crops, but also provide information on management tools and market analyses.

The most important barriers found on the irrigation adoption could be circumvented by the development of irrigation projects to subsidize a part of the high implementation costs. Additionally, special line of credit should be available to producers that are willing to adopt

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<sup>7</sup> We used an exchange rate of December 2014: US\$ 1 equals to R\$ 2.639.

<sup>8</sup> Consecitrus has been in discussion more deeply since 2011 as a result of the fusion of two of the main juice processor companies: Citrosuco and Citrovita.

irrigation but do not have water close or inside their properties or they should be given reduced energy fees besides the already existing ones, such as green tariffs.

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