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A Path Model of the Intention to Adopt Variable Rate Irrigation in Northeast Italy

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Abstract

Irrigated agriculture determines large blue water withdrawals, and it is considered a key intervention area to reach sustainable development objectives. Precision agriculture technologies have the potential to mitigate water resource depletion that often characterizes conventional agricultural approaches. This study investigates the factors influencing farmers' intentions to adopt variable rate irrigation (VRI) technology. The Technology Acceptance Model 3 (TAM-3) was employed as a theoretical framework to design a survey to identify the factors influencing farmers' decision-making process when adopting VRI. Data were gathered through quantitative face-to-face interviews with a sample of 138 fruit and grapevine producers from the Northeast of Italy (Veneto, Emilia-Romagna, Trentino-Alto Adige, Friuli-Venezia Giulia). Data were analyzed using partial least squares path modelling (PLS-PM). The results highlight that personal attitudes, such as perceived usefulness and subjective norm, positively influence the intention to adopt VRI. Also, the perceived ease of use positively affects intention, but it is moderated by subject experience.

Keywords: Precision agriculture, Intention to adopt a technology, Attitudes towards the use of technology, Technology acceptance model, Variable rate irrigation, Fruit production, Grapevine production

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1. Introduction

Irrigated agriculture can be considered a key element in reaching sustainable development objectives since approximately 70% of water worldwide is used for agriculture (Marchal et al., 2011). During the last century, impacts of irrigation have been of pivotal importance, not just in terms of agricultural development. They have embraced relevant rural developments while transforming the health and the entire way of life in rural areas (Molden, 2013). Today, irrigated agriculture must cope with several threats and challenges such as water scarcity, mitigation of negative environmental impacts associated with conventional agriculture, and climate change effects (FAO, 2016). In this context, site-specific approaches associated with improvements in operation and management of irrigation and fertigation practices can represent feasible solutions.

Among the various approaches, variable rate irrigation technology (VRI) is a branch of precision agriculture (PA) that allows better control of the water used in irrigation systems, improves resource management and control, and increases water use efficiency. This approach is essentially based on collecting information on crop water need, analysing data to produce irrigation prescription maps, and precisely applying water to the soil. For instance, the detection of spatial variability of soil and crops' hydrological characteristics can be conducted using proximal and remote sensing technologies. The spatial data can be managed through Geographical Information Systems (GIS) to obtain homogeneous management zones for applying a dedicated irrigation schedule (Haghverdi et al., 2015). Finally, VRI is applied thanks to irrigation systems able to distribute water to the management zones, and this may take the form of pivot, sprinkler, or drip irrigation, depending on the type of crop.

Very few contributions have documented water conservation strategies using VRI, particularly in viticulture. Ortuani et al., (2019) experimented a VR drip irrigation in Northern Italy, achieving a reduction of water usage by 18% compared to the farmer's habits and a more homogeneous grape maturation, without affecting yield and product quality. Balafoutis et al., (2017) experienced a VRI coupled with a VR fertilizer application in North-eastern Greece that reduced grape carbon footprint. Klein et al., (2018) presented a fully

automated large-scale closed-loop VR drip irrigation system in California, resulting in a 26% yield increase in the second year and an average increase of 16% in water use efficiency.
Although currently underutilized, VRI technology has the potential to positively impact water use efficiency, water, and energy conservation, with positive effects on the environment. Thus, there is a critical need to develop fully integrated VRI technology systems to mitigate water scarcity and negative environmental impacts associated with conventional agriculture, as well as climate change effects.

Among existing adoption barriers, Evans et al. (2013) hint high technology marginal costs, poor economic incentives, limited research support to growers and lack of know-how, particularly regarding data analysis. Rather than focusing on the most common objective factors influencing technology adoption, such as monetary costs and benefits, this study aimed to understand what factors affect growers' intention to adopt a VRI approach to irrigate their orchards and vineyards. The goal is to highlight those behavioural aspects that can be addressed by political, technical and peer-to-peer mediation to facilitate PA uptake.
The behavioural aspect is especially important for adopting new technologies (Davis & Venkatesh, 2004). Therefore, firstly, we considered a theoretical model of the growers' behaviour. A relevant body of research has addressed the examination of factors affecting information technology acceptance, laying its foundation in the technology acceptance model (TAM), initially developed by Davis (1989) to explain computer-usage behaviour. Several models and theories have been discussed in the field of information technology acceptance, such as the theory of planned behaviour (TPB) (Ajzen, 1991), the diffusion of innovation (DOI) theory (Rogers, 1962; Rogers et al., 2019), and the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003) but, apparently, TAM still is the dominant model for investigating factors affecting users' acceptance of novel technical systems (Legris et al., 2003; Rahimi et al., 2018)
TAM is based on the theory of reasoned action (TRA) proposed by Fishbein and Ajzen (1975), who demonstrated that the behaviour is best predicted by intentions determined both by the person's attitude and subjective norm concerning the behaviour. In its earlier version, TAM states that two particular beliefs, the *Perceived ease of use* and the *Perceived*

usefulness, referring respectively to the degree to which the user expects the technology to be free of effort, and the prospective user's subjective probability to use the technology, will increase his job performance. An expanded version of the model, TAM2 (Venkatesh & Davis, 2000), was developed by introducing new determinants for the *Perceived usefulness* and two moderators (*Experience* and *Voluntariness*). The latest version of TAM was labelled TAM-3 (Venkatesh & Bala, 2008). TAM-3 shows a list of determinants for the *Perceived ease of use* also. Determinants play the role of external variables influencing individual perceptions that, in turn, determine behaviours. The intention to adopt a certain technology was included within the construct *Attitude toward Use*. Figure 1 concisely illustrates TAM-3, considering both Davis (1989) and Venkatesh & Bala (2008) contributions.

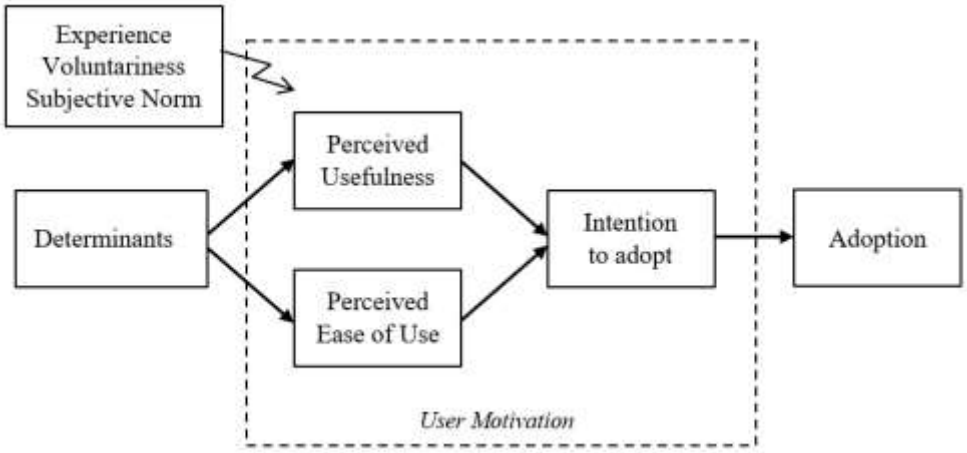

Figure 1 – A concise illustration of TAM-3.

Thus, in this study, we assume that the intention to adopt VRI is affected by perceptions and attitudes regarding the technology and the social context. The TAM-3 constructs were operationalized through a set of Likert scales, and the empirical data necessary to test the strength of the relationships between constructs were collected using a questionnaire-based survey.

The study was conducted in the Northeast of Italy. This area includes the region of Friuli Venezia Giulia, Veneto, Trentino Alto Adige, and part of the Emilia-Romagna region, and it is considered one of the most productive areas in Europe even regarding food production. Among the most famous products that characterize this area, it is worth to mention Prosecco

(a DOC or DOCG white wine produced in a large area spanning nine provinces in the Veneto and Friuli Venezia Giulia regions), and the South Tyrolean Apple PGI produced in Trentino Alto Adige. Fruit growing is one of the most important agricultural activities in Emilia-Romagna, a region that is considered Italy's main orchard. This wide area was affected in the summer of 2017 by a severe drought, and this negative contingency could make VRI technology of interest to those farmers who found necessary to mitigate the problem of water scarcity.

The study is organized as follows. In Section 2, the methodological framework is described, specifying the determinants of the intention to adopt VRI technology the underlying hypotheses, as well as the constructs measurement method; thus, the method adopted to administrate the questionnaire to collect data from growers is described, and data analysis conducted using partial least square path modelling (PLS-PM) is explained. The growers' sample description is reported in Section 3. Sections 4 and 5 report research results and discussion. Section 6 concludes the study, with recommendations for PA stakeholders and policy-makers.

2. Materials and methods

2.1 Theoretical framework and construct operationalization

Following the TAM-3 theoretical model, we set the construct "Intention to adopt VRI" (INT) as the dependent variable; its value is affected by two endogenous constructs, *Perceived ease of use* (PEU) and the *Perceived usefulness* (PUF), and the exogenous construct *Subjective norms* (SN) and a series of interaction variables. Several external variables were chosen in line with Venkatesh & Bala (2008) as potential direct or indirect determinants of the PEU and PUF constructs, as reported in Table 1. Each variable was defined by a set of items (typically 3 or 4) included in the structured questionnaire that has been pre-tested in November 2017 with 15 growers. The final version of the items used in the survey is reported in the Appendix. In considering the variables of TAM-3 model, we decided to exclude the endogenous construct *Objective Usability* (OU), defined as a "*comparison of systems based on the actual level (rather than perceptions) of effort required to completing specific tasks*"

(Venkatesh, 2000). The reason is that we perceived such adjustment not easily applicable in the context of VRI technology; the pre-test confirmed this hypothesis: growers had no sufficient background to judge any actual level of effort required to use VRI, having no experience in any of the technology and equipment which define VRI. Therefore, including OU would have led to misrepresentation. Table 1 shows the TAM-3 version with the set of variables adopted in this study.

2.2. Survey procedure

The requirements to join the survey were that growers were responsible for decision-making in their farm and still have not adopted VRI technology. The final questionnaire was structured in three parts: (1) intention to adopt VRI technology and attitudes toward novel technology, (2) grower demographics, and (3) main farm production and economic characteristics, with single- and multiple-choice questions. In part (1), respondents were asked to give their opinion about statements related to TAM-3 variables according to a 7-point Likert-like scale, ranging from 1 (totally disagree) to 7 (totally agree). These items were presented in a randomized order to avoid order bias. Prior to part (1), general information about PA and VRI was provided. At first, participants were told the following:

"Precision agriculture is a farming approach for agronomic interventions that considers the actual needs of the crop and soil characteristics so that it can calibrate the application of nutrients within the field. In this way, it can lead to environmental and economic benefits."

Then, specific information about VRI technology features was provided, in order to make the participants aware of VRI potentials and benefits, with the following:

"Variable Rate Irrigation is a site-specific/plant-specific approach regarding better water management. Irrigation water can be applied when and where it is needed, resulting in increased water efficiency. It combines several precision agriculture tools that enable a centralized water use control. Variable Rate Irrigation allows growers to apply water at different time rates, based on specific crop needs."

In addition, to help participants better understand VRI, a picture describing the use of an irrigation-management software was shown to them and explained. The questionnaire was

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Table 1 – TAM-3 Hypotheses and paths

Hypotheses	**Path**
H1. Perceived Usefulness affects the intention to adopt VRI.	PUF → INT
H2. Perceived Ease of Use affects the intention to adopt VRI.	PEU → INT
H3. Subjective Norm affects the intention to adopt VRI.	SN → INT
H4. Perceived Ease of Use moderated by Experience affects the intention to adopt VRI.	PEU*EXP → INT
H5. Subjective Norm moderated by Experience affects the intention to adopt VRI.	SN*EXP → INT
H6. Subjective Norm moderated by Voluntariness affects the intention to adopt VRI.	SN*VOL → INT
H7. Perceived Ease of Use affects the Perceived Usefulness of VRI.	PEU → PUF
H8. Image affects the Perceived Usefulness of VRI.	IM → PUF
H9. Result Demonstrability affects the Perceived Usefulness of VRI.	RD → PUF
H10. Subjective Norm affects the Perceived Usefulness of VRI.	SN → PUF
H11. Job Relevance affects the Perceived Usefulness of VRI.	REL → PUF
H12. Job Relevance moderated by Output Quality affects the perceived Usefulness of VRI.	REL*OQ → PUF
H13. Subjective Norm moderated by Experience affects the Perceived Usefulness of VRI.	SN*EXP → PUF
H14. Perceived Ease of Use moderated by Experience affects the Perceived Usefulness of VRI.	PEU*EXP → PUF
H15. Output Quality moderated by Relevance affects the Perceived Usefulness of VRI.	OQ*REL → PUF
H16. Perception of External Control affects the Perceived Ease of Use of VRI.	PEC → PEU
H17. Perceived Enjoyment affects the Perceived Ease of Use of VRI.	ENJ → PEU
H18. Self-Efficacy in performing tasks using VRI affects the Perceived Ease of Use of VRI	SE → PEU
H19. Anxiety facing with the possibility of using VRI affects the Perceived Ease of Use of VRI.	ANX → PEU
H20. Playfulness with VRI affects the Perceived Ease of Use of VRI.	PLY → PEU
H21. Anxiety facing the possibility of using VRI moderated by Experience affects the Perceived Ease of Use of VRI.	ANX*EXP → PEU
H22. Playfulness with VRI moderated by Experience affects the Perceived Ease of Use of VRI.	PLY*EXP → PEU
H23. Perceived Enjoyment moderated by Experience affects the Perceived Ease of Use of VRI.	ENJ*EXP → PEU
H24. Subjective Norm affects Image	SN → IM

administered through face-to-face interviews with a sample of grape and fruit growers in the Northeast of Italy. Surveys have been administered with fruit and grape growers during "FuturPera" Agricultural fair (16-18 November 2017, Ferrara, Italy). In a second moment, participants were asked to fill out an online survey until February 2018. The sampling

procedure was enriched by a snowballing sample procedure, with some new participants suggested by whom was met at the fair.

2.3. Data analysis

Data from the questionnaire related to TAM-3 variables were processed with partial-least square path modelling (PLS-PM) (Tenenhaus et al., 2005) based on the statistical package "plspm" available in R (Sanchez, 2013). Path modelling applied to our data allows measuring how much each factor could influence the decision to adopt the VRI technology. PLS-PM is a multivariate technique used to test path dependence models and estimate the model parameters that minimize the residual variance of the dependent variables (Hair et al., 2017). In PLS-PM, constructs are estimated as a linear combination of their items through simple regression. The algorithm adopted follows a sequential procedure that can be divided into three stages: (1) calculating the weights to compute variable scores based on constructs' items, (2) estimating the path coefficients (inner model) through least squares regressions, and (3) obtaining the path loadings by means of simple correlations (outer model).

Moderating effects of Experience (EXP) and Voluntariness (VOL) as described in Table 1 were considered using the Product Indicator approach (Sanchez, 2013), i.e. adding new constructs in the form of product-indicators of the new latent variables. To have an idea, the new items related variable PEU*EXP resulted from the product between the 2 items of PEU and the 3 items of EXP; in general, for each moderated construct, n*k additional items were obtained from the product between the n items of moderator variable with the k items of latent variable.3. Sample description

In total, 138 participants completed the survey. The net response rate was around 25%, and the completion rate was around 10% which is reasonable in this type of survey. Seventy-one participants (51.4%) were from Emilia-Romagna, 29 (21.0%) were from Veneto, 21 (15.2%) were from Trentino Alto Adige, and 17 persons (12.3%) were from Friuli Venezia Giulia. As expected, most respondents were male (89%), with an average age of 43. The average number of years of experience working in agriculture was 21. Most respondents graduated from high school (45%), and the number of growers with a university degree was quite high (38%). The average total farm surface was 30 ha, ranging from 1 ha to 200 ha.

In terms of PA technology adoption, 34.5% of respondents declared they had already adopted at least one technology other than VRI. The adopted technologies were, in descending order: sensors monitoring humidity and temperature (62.5%), guidance technology (47.9%), automated section control (30%), monitoring technology and VR technology, both with 29.2%. The high adoption rate was surprisingly beyond expectations but, on the other hand, most of the respondents declared to use just sensors monitoring the environment, which may be representative of the first step of a more comprehensive PA adoption process.

3. Results

3.1. Reliability and consistency of the model

Before examining the model result, its reliability and validity are examined. In particular, we evaluated the following three aspects: 1) internal and 2) external consistency of the model, and 3) possible similarities between latent variables. This study considered the threshold level of 0.7 to assess model adequacy based on Cronbach's alpha and the Dillon-Goldstein's rho statistics (Fornell & Larcker, 1981; Sanchez, 2013). For almost all constructs (17 out of 19), Cronbach's alpha exceeded 0.7, with the exceptions of SN (Subjective Norm, 0.65) and PEC (Perception of External Control, 0.62). For these two constructs, Cronbach's alpha is still higher than 0.6, which can be considered acceptable for marketing research. Dillon-Goldstein's rho is higher than 0.7 for all constructs (Table 2). These statistics indicate an overall good internal consistency of the model and the main constructs' internal reliability.

The external consistency reflects constructs' consistency in explaining latent variables. In this case, item loadings (>0.7) are used to evaluate convergent validity. A loading greater than 0.7 means that its latent construct captures more than 0.72 ~ 50% of the variability in an indicator. In the first run almost all the 71 item loadings were higher than 0.7, except PEU_02 (0.69), PEU_01 (0.66), RD_01 (0.65), SN_02 and PEC_01 (both 0.64), and PEC_04 (0.46). This outcome suggested removing alarming items considered unfit. Hence, we started to remove the items with the lowest loading iteratively while checking the model's internal and external consistency. By the end, PEC_04, SN_02, RD_01 and PEU_01 were removed from the constructs. Although we observed a slight decrease in Cronbach's alpha for PEC, SN, RD

Table 2 – Internal consistency of TAM-3 constructs

Construct	Cronbach's alpha	Dillon-Goldstein's rho
OG*REL	0.966	0.972
SN	0.630	0.844
IM	0.801	0.883
REL	0.839	0.904
RD	0.685	0.864
VOL*SN	0.897	0.928
EXP*SN	0.909	0.936
SE	0.649	0.851
PEC	0.493	0.798
ANX	0.707	0.872
PLY	0.759	0.862
ENJ	0.812	0.888
EXP*PEU	0.908	0.929
EXP*ENJ	0.925	0.942
EXP*PLY	0.937	0.950
EXP*ANX	0.843	0.894
PEU	0.454	0.786
PUF	0.789	0.877
INT	0.821	0.918

and PEU constructs, respectively from 0.62 to 0.49, from 0.65 to 0.63, from 0.62 to 0.69, and from 0.60 to 0.45, Dillon-Goldstein's rho values were still fine for the same constructs: 0.78 for PEC (same as before), 0.84 for SN (increased from 0.81), 0.86 for RD (increased from 0.80), and 0.79 for PEU (same as before). Hence, we decided to keep the model version with the highest model external consistency with almost no effects in internal construct consistency. Last, possible similarities between latent variables were excluded by checking items' cross-loadings: no traitor indicators were observed.

After the quality of the measurement model was assessed with success, the next step is to assess the quality of the structural part. This aspect was evaluated by considering a pseudo-R^2 associated with the regression with the exogenous dependent variables, the goodness of fit (GoF), and the average variance extracted (AVE). The pseudo-R^2 coefficients were calculated as 0.5499 for the Intention to adopt (INT), 0.7603 for the Perceived Usefulness (PUF), and 0.5842 for the Perceived Ease of Use (PEU), indicating reasonable fit for all three.

GoF was calculated as 0.6421, indicating a good fit for the whole model. All constructs' values of AVE were above 0.5 (the least was PEC with 0.54).

As expected, Subjective Norm (SN) plays a pivotal role, both considering the direct effect (H3) and as moderated by Voluntariness (VOL) (H6) and Experience (EXP) (H5). Intention to Adopt (INT) appears to be determined by Perceived Ease of Use (PEU), only if moderated by Experience (EXP) (H4), while the total effect of Perceived Ease of Use (PEU) on Intention to Adopt (INT) appears to be not significant (H2).

Turning to the Perceived Usefulness (PUF), the most evident determinant is Job Relevance (REL) moderated by Output Quality (OQ) (H15). Alone, Job Relevance (REL) was found to be negatively correlated with Perceived Usefulness (PUF) (H11), and this may appear in contrast with expectations. The correlation between Result Demonstrability (RD) and Perceived Usefulness (PUF) was found to be positive and meaningful (H9). Less significant but still positive were the relationships with Subjective Norm (SN), both alone (H10) and moderated by Experience (EXP) (H13), and Image (IM) (H8). On the contrary, we observed a negative relationship between Perceived Usefulness (PUF) and Perceived Ease of Use (PEU) if moderated by Experience (EXP) (H14), which was found to be positive if not moderated by Experience (EXP) (H7); this suggests that with increasing experience, the influence of Perceived Ease of Use (PEU) on Perceived Usefulness (PUF) will be weaker.

3.2. Path modelling results

Table 3 shows the results associated with the PLS-PM model from the original sample (N=138). In terms of factors affecting the Intention to Adopt (INT), four out of six hypotheses were clearly verified (H1, H3, H4, and H6).

Regarding Perceived Ease of Use, a strong positive correlation was found with Perceived Enjoyment (ENJ) (H17). However, with increasing experience, the influence of Perceived Enjoyment (ENJ) on Perceived Ease of Use (PEU) will be significantly weaker (H23). On the contrary, Experience (EXP) positively affects the influence of Playfulness (PLY) on Perceived Ease of Use (PEU) (H22). This outcome appears to be reasonable: cognitive spontaneity characterizing Playfulness (PLY) increases with experience, while the enjoyment aside from the technology's performance may affect just less experienced subjects.

Table 3 – PLSM-PM results of TAM-3 constructs

Hp	Path	Direct Relationship	Indirect Relationship	Total	R^2
H3.	SN → INT	0.3045	0.0415	0.3460	INT: 0.550
H1.	PUF → INT	0.3032	-	-	
H4.	PEU*EXP → INT	0.3074	-0.0310	0.2764	
H6.	SN*VOL → INT	0.2124	-	-	
H5.	SN*EXP → INT	-0.0951	0.0366	-0.0585	
H2.	PEU → INT	-0.0415	0.0392	-0.0023	
H15.	OQ*REL → PUF	0.6584	-	0.6584	PUF: 0.760
H9.	RD → PUF	0.3301	-	0.3301	
H11.	REL → PUF	-0.2691	-	-0.2691	
H10.	SN → PUF	0.0895	0.0474	0.1368	
H7.	PEU → PUF	0.1293	-	0.1293	
H13.	SN*EXP → PUF	0.1207	-	0.1207	
H14.	PEU*EXP → PUF	-0.1024	-	-0.1024	
H8.	IM → PUF	0.0812	-	0.0812	
H23.	ENJ*EXP → PEU	-0.7806	-	-0.7806	PEU: 0.584
H17.	ENJ → PEU	0.6739	-	0.6739	
H22.	PLY*EXP → PEU	0.5791	-	0.5791	
H19.	ANX → PEU	-0.3125	-	-0.3125	
H21.	ANX*EXP → PEU	0.2650	-	0.2650	
H16.	PEC → PEU	0.2616	-	0.2616	
H18.	SE → PEU	0.2572	-	0.2572	
H20	PLY → PEU	-0.1034	-	-0.1034	
H24	SN → IM	0.5832	-	0.5832	IM: 0.340

As expected, Anxiety (ANX) was found to affect negatively Perceived Ease of Use (PEU) (H19), with Experience (EXP) mitigating this effect (H21). A positive correlation was also observed with Perception (PEC) (H16); this confirms the theoretical hypothesis that organizational resources may favour Perceived Ease of Use (PEU). A similar effect was also observed for Self-Efficacy (SE) (H18). Surprisingly, increased levels of Playfulness (PLY) are associated with diminishing Perceived Ease of Use (PEU) (H20), albeit with a low level of significance.

Last, Subjective Norm (SN) was found to be significantly affecting Image (IM) (H24), in line with theoretical assumptions.

Figure 2 shows the TAM-3 model applied to growers' intention to adopt VRI technology.

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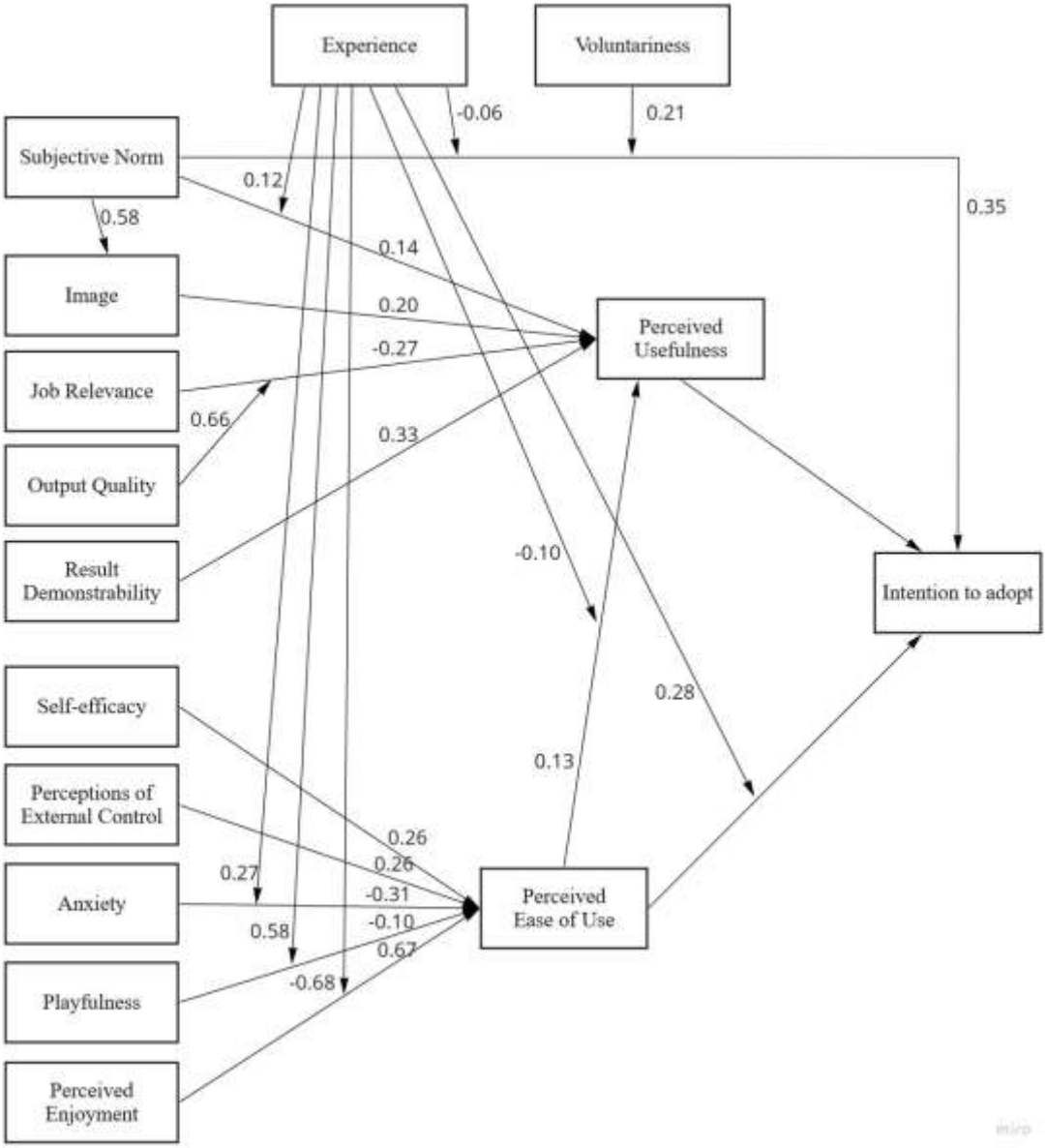

Figure 2 – PLSM-PM of TAM-3 constructs.

4. Discussions

Several factors affect growers' decisions to adopt VRI technology in Northeast Italy. This study confirms that the Subjective norm construct, which describes social pressure and

neighbour influence, mostly affects the intention to adopt this technology. In addition, it has a remarkable effect when moderated by subject's voluntariness to adopt. The intention to adopt is positively affected with the same magnitude also by the Perceived Usefulness (PUF) and by the Perceived Ease of Use (PEU), only if it is moderated by Experience.

The remaining constructs appear quite strong, with significant effects of TAM-3 determinants on PEU and PUF. The role of Experience is recognized with a higher emphasis on PEU determinants rather than on those of PUF.

Overall, most of the theoretical assumptions of TAM-3 were verified, but somehow subjects' attitudes regarding VRI technology emerge with their peculiarities. Results found that Job Relevance (REL) and Output Quality (OQ) are the two important determinants of PUF, which positively affect the intention to adopt VRI. Nevertheless, Job Relevance (REL) was negatively correlated with Perceived Usefulness (PUF). This outcome is not expected, but it might be correlated with the fact that the participants' information during the data collection did not convince them. It can also be related to the fact that the majority of participants had no or little experience with PA.

Overall, these results are in line with other studies which have measured intentions to adopt PA. In particular, the prominent role played by the Perceived Usefulness (PUF) in the decision to adopt PA technologies was also recognized in Adrian et al. (2005), in which also the weak direct effect of the Perceived Ease of Use (PEU) was acknowledged. Similar findings were also observed in Lu et al. (2015). Going back to the analysis of TAM-3 relationships between determinants, it was found that the Perceived Enjoyment (ENJ) largely influenced the Perceived Ease of Use (PEU), in accordance with (Shyu & Huang, 2011). Also, Result Demonstrability (RD) and Job Relevance (REL) moderated by Output Quality (OQ) have shown a remarkable influence on PUF.

5. Conclusions

To foster the adoption of this technology, and in general of PA technologies, in this study, we examined the factors that affect the intention to adopt VRI technology and applied the TAM-3 model to a sample of fruit and grape growers from Northeast Italy. Model items were mathematically assessed with PLS-PM. TAM-3 model gave satisfactory outcomes and

explained to a good extent the intention to adopt VRI technology. The findings highlight that several factors concur to determine individual attitudes and behaviours that may favour adopting this type of system. Subjective norms, perceived usefulness and perceived ease of use moderated by experience are the most important constructs for farmers when adopting new technology. In turn, these constructs are associated with several determinants, of which it is worth to mention job relevance and output quality, result demonstrability, and perceived enjoyment. These associations can pave the ground to numerous actions that service providers, technology suppliers, public authorities and scholars may consider to foster PA technology adoption. In particular, this study suggests several aspects belonging to different agricultural businesses and stakeholders should be stressed to promote the adoption of VRI. PA technology providers should emphasize the relevance of VRI to growers, by giving examples of farmers who successfully adopt it, have fruitful results and enjoy the technology. Researchers should better demonstrate benefits related to PA adoption. Public authorities should provide appropriate policies as well as financial and technical support to encourage producers to adopt the technology while reducing possible anxiety. Moreover, as already suggested by Evans et al. (2013), there is a large need to educate government boards and bankers on the potential benefits of VRI systems. In this context, the challenge is to demonstrate that VRI will improve water management and increase farm net returns.

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References

Adrian, A. M., Norwood, S. H., & Mask, P. L. (2005). Producers' perceptions and attitudes toward precision agriculture technologies. In *Computers and Electronics in Agriculture* (Vol. 48, Issue 3, pp. 256–271). https://doi.org/10.1016/j.compag.2005.04.004

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Balafoutis, A., Koundouras, S., Anastasiou, E., Fountas, S., & Arvanitis, K. (2017). Life

Cycle Assessment of Two Vineyards after the Application of Precision Viticulture Techniques: A Case Study. *Sustainability*, *9*(11), 1997. https://doi.org/10.3390/su9111997

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems*. https://doi.org/10.2307/249008

Davis, F. D., & Venkatesh, V. (2004). Toward preprototype user acceptance testing of new information systems: implications for software project management. *Engineering Management, IEEE Transactions On*, *51*(1), 31–46. https://doi.org/10.1109/TEM.2003.822468

Evans, R. G., LaRue, J., Stone, K. C., & King, B. A. (2013). Adoption of site-specific variable rate sprinkler irrigation systems. In *Irrigation Science* (Vol. 31, Issue 4, pp. 871–887). Springer. https://doi.org/10.1007/s00271-012-0365-x

FAO. (2016). Coping with Water Scarcity in Agriculture: a Global Framework for Action in a Changing Climate. In *FAO*.

Fishbein, M., & Ajzen, I. (1975). Belief, Attitude, Intention, and Behaviour: An Introduction to Theory and Research. Reading, MA: Addison-Wesley.

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*. https://doi.org/10.2307/3151312

Haghverdi, A., Leib, B. G., Washington-Allen, R. A., Ayers, P. D., & Buschermohle, M. J. (2015). Perspectives on delineating management zones for variable rate irrigation. *Computers and Electronics in Agriculture*, *117*, 154–167. https://doi.org/10.1016/j.compag.2015.06.019

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling* (2nd ed.). Sage.

Kahan, D. (2013). Managing risk in farming. In *Farm management extension guide*.

Klein, L. J., Hamann, H. F., Hinds, N., Guha, S., Sanchez, L., Sams, B., & Dokoozlian, N. (2018). Closed Loop Controlled Precision Irrigation Sensor Network. *IEEE Internet of Things Journal*, *5*(6), 4580–4588. https://doi.org/10.1109/JIOT.2018.2865527

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information and Management*, *40*(3), 191–204. https://doi.org/10.1016/S0378-7206(01)00143-4

Lu, Y., Lu, Y., Wang, B., Pan, Z., & Qin, H. (2015). Acceptance of government-sponsored agricultural information systems in China: the role of government social power. *Information Systems and E-Business Management*, *13*(2), 329–354. https://doi.org/10.1007/s10257-014-0235-6

Marchal, V., Dellink, R., Vuuren, D. Van, Clapp, C., Château, J., Lanzi, E., Magné, B., & Vliet, J. Van. (2011). *OECD Environmental Outlook to 2050 Chapter 3: Climate Change*. *November*, 90. https://doi.org/10.1787/9789264122246-en

Molden, D. (2013). Water for food water for life: A Comprehensive assessment of water management in agriculture. In *Water for Food Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. https://doi.org/10.4324/9781849773799

Ortuani, B., Facchi, A., Mayer, A., Bianchi, D., Bianchi, A., & Brancadoro, L. (2019).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2020 doi:10.20944/preprints202012.0786.v1

Assessing the effectiveness of variable-rate drip irrigation on water use efficiency in a Vineyard in Northern Italy. *Water (Switzerland)*, *11*(10). https://doi.org/10.3390/w11101964

Rahimi, B., Nadri, H., Afshar, H. L., & Timpka, T. (2018). A systematic review of the technology acceptance model in health informatics. In *Applied Clinical Informatics* (Vol. 9, Issue 3, pp. 604–634). Georg Thieme Verlag. https://doi.org/10.1055/s-0038-1668091

Rogers, E. (1962). *Diffusion of innovations.* Free Press of Glencoe.

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2019). Diffusion of innovations. In *An Integrated Approach to Communication Theory and Research, Third Edition* (pp. 415–433). Taylor and Francis. https://doi.org/10.4324/9780203710753-35

Sanchez, G. (2013). PLS Path Modeling with R. *R Package Notes*.

Shyu, S. H. P., & Huang, J. H. (2011). Elucidating usage of e-government learning: A perspective of the extended technology acceptance model. *Government Information Quarterly*, *28*(4), 491–502. https://doi.org/10.1016/j.giq.2011.04.002

Tenenhaus, M., Vinzi, V. E., Chatelin, Y. M., & Lauro, C. (2005). PLS path modeling. *Computational Statistics and Data Analysis*, *48*(1), 159–205. https://doi.org/10.1016/j.csda.2004.03.005

Venkatesh, V. (2000). Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model. *Information Systems Research*, *11*(4), 342–365. https://doi.org/10.1287/isre.11.4.342.11872

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273–315. https://doi.org/10.1111/j.1540-5915.2008.00192.x

Venkatesh, V., & Davis, F. D. (2000). Theoretical extension of the Technology Acceptance Model: Four longitudinal field studies. *Management Science*. https://doi.org/10.1287/mnsc.46.2.186.11926

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly: Management Information Systems*, *27*(3), 425–478. https://doi.org/10.2307/30036540

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 31 December 2020 doi:10.20944/preprints202012.0786.v1

Appendix

Original items used for the definition of constructs

Item	Definition
INT_01	I am sure that I will use VRI in the near future
INT_02	I intend to use VRI in the near future
INT_03*	If significant barriers did not exist, I will use VRI in the near future
SN_01	Persons who influence my decisions think I should use VRI
SN_02**	Many producers I know have already used VRI
SN_03	My clients think I should use VRI
PUF_01	VRI could make it easy to do my job
PUF_02	VRI could increase my productivity
PUF_03	VRI gives me greater control over my job
IM_01	Using VRI would make me feel better than my colleagues
IM_02	Using VRI could create good image to my farm
IM_03	Producers who use VRI will have more prestige than those who do not
REL_01	In my job, using VRI is important
REL_02	VRI could be useful for my farm
REL_03	The use of VRI is relevant to my farm activities
OQ_01	I consider the output of using VRI will be excellent
OQ_02	Using VRI will improve the quality of my products
OQ_03	Using VRI will allow me to control the quality of my products
RD_01**	The result of using VRI will be apparent to me
RD_02	I believe I could communicate to others the consequences of using VRI
RD_03	I believe I would have no problem explaining to others the benefits/drawbacks of using VRI
PEU_01**	VRI could be used easily
PEU_02	Using VRI will not require a lot of effort
PEU_03	It would be easy for me to become skilful at using VRI in the farm
SE_01	I would feel comfortable using VRI on my own
SE_02	I am confident in my ability to use VRI
SE_03*	I am proficient in the use of a computer
PEC_01	There are public policies supporting producers to use VRI
PEC_02	I could receive the necessary financial support to invest in VRI
PEC_03	I could receive the necessary technical support and help while I use VRI
PEC_04**	I think I would need a technical support when adopting VRI
ANX_01	I get nervous when working with new technology
ANX_02	Working with a computer makes me nervous
ANX_03*	Computer makes me feel uneasy
PLY_01	I am creative when using new technology
PLY_02	I am calm when using new technology
PLY_03	I am fast learning when using new technology

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ENJ_01	I think I might enjoy using VRI
ENJ_02	Using VRI will be pleasant for me
ENJ_03	Using VRI will be fun/entertaining
VOL_01	My use of VRI will be voluntary
VOL_02	The decision to adopt VRI depends entirely on me
VOL_03*	I will use VRI even when my clients did not ask me to use
VOL_04*	Although it might be helpful, using VRI is not compulsory to me
EXP_01	I have experience using new technology in farm activities
EXP_02	I have experience using other precision agriculture technologies
EXP_03	I have experience using computer in farm management

*Dropped after pre-test evaluation and internal consistency check
**Dropped after constructs' external consistency check