

Determinants of Adoption of Technologies for Cashew Production in Nampula, Mozambique

ABSTRACT

This study analyzed determinants of adoption and intensity of use of Technologies for Cashew Production (TCP) in Nampula, Mozambique. We used cross-sectional data collected from 258 farmers' household in 2016. A double-hurdle model was employed to assess the determinants of adoption and intensity of planting grafted seedlings and use of fungicide. The results showed that 27% of the households planted grafted seedlings with an intensity of seven seedlings annually, and 46% of famers used fungicide at 38% of intensity. Empirical results revealed that the major determinants of adoption of TCP are formal education, price of cashew nut and access to extension services. While the intensity of use is influenced by age of the household head and availability of family labor. Training in cashew was important factor for adoption and intensity of use of grafted seedlings. Adoption was higher in the district of Angoche and lower in Erati for both assessed technologies. Enhancing extension services and ensuring better cashew nut price policy are important measures for increasing adoption of grafted seedlings and fungicide application.

Keywords: Intensity of adoption, grafted seedlings, fungicide, and double-hurdle model.

1. INTRODUCTION

Cashew is the third export major crop generating foreign currency and job in Mozambique, after sugar cane and cotton [1]. According to [2], in 2006 the global excess demand of cashew nut was estimated at 430, 000 metric tons of raw nuts, valued at US\$270 Million,

21 growing at an average of 6.5% annually. Between 2005 and 2009, the average contribution
22 of cashew nut to the national agricultural exports was 12% [3].

23 In the late 1960s and early 1970s, Mozambique was one of the major producers and
24 exporters of cashew nut in the world [3]. The highest production was achieved in 1972/73
25 with the commercial amount of 216 thousand tons of raw cashew nut, 50.8% of the world
26 production [3]. Nevertheless, after 1975, the cashew production decreased drastically due to
27 the civil war, inconsistent policies, oldness of cashews and incidence of diseases (powdery
28 mildew and anthracnose) [4, 5, 3, 6]. In the last decade, the highest production was
29 achieved in 2011, with 113 thousand tons [7]. In 1998, the government introduced, through
30 the Institute for Cashew Promotion (INCAJU), three programs for increasing production and
31 productivity [4], namely: i) phytosanitary program; ii) integrated cashew management and iii)
32 promote the processing of small and medium cashew industry [8].

33 INCAJU multiplies and distributes grafted seedlings to farmers, who pay a subsidized price.
34 In 2017, smallholder farmers purchased a grafted seedling at US\$0.08, and farmer's
35 associations payed US\$ 0.17, while the commercial farmers are charged US\$0.34 per
36 seedling [8]. On the other hand, the application of fungicide is conducted by private service
37 providers, who get approval and support from INCAJU. Farmers do not pay the cost of
38 chemicals, because it is 100% subsidized by the government. They pay only price for the
39 spraying service. For 2017, the spraying cost was set at US\$0.76 per cashew tree in the
40 Northern and Central regions, including Nampula, and US\$1.02 in the Southern region¹ [8].

41 In 2011/12, the use of grafted seedlings in Nampula was 5.13%, with intensity of seven
42 seedlings annually, and 12% of households used fungicides [9]. These figures suggest that
43 the majority of farmers are not yet using these technologies as part of cashew management.
44 Therefore, this study aims at identifying factors influencing adoption and intensity of use of
45 grafted seedlings and fungicide in Nampula, Mozambique. This information can be used for

¹ The full spraying cost including the chemicals is US\$1.55 per tree in the Northern and Central regions and US\$2.37 in the Southern.

46 improving the current approaches on promoting the use of Technologies for Cashew
47 Production (TCP).

48 2. METHODOLOGY

49 2.1. Description of the study area

50 The study was carried out in the Nampula province, one of the ten provinces in
51 Mozambique. It is located in the coastal Northeastern of the country, with a total of 79,010
52 km², bordered to the East by the Indian Ocean. According to the 2007 Census, the
53 population is estimated at more than 4 million inhabitants, representing more than 19% of
54 the national population, making it the most populated. There is a total of 829,642 agricultural
55 holdings, representing 22%, the highest among the eleven provinces including Maputo city.
56 However, among the 829,642 holdings, 828,788 are small scale holdings [10].

57 Nampula covers mostly two of ten agro-ecological regions (R7 and R8) of Mozambique [11].
58 R7 has altitude between 200 and 1000 meters. The topography is flat to wavy and the soil
59 fertility is moderate to good. The annual precipitation is between 1000 to 1400 mm. In R8 the
60 altitude varies between 0 and 200 meters and the topography is generally flat to soft wavy.
61 The annual precipitation is 800 to 1200 mm. Both regions present during the year
62 temperatures around 25° C [11]. Nampula is the major producer of cashew in Mozambique,
63 with a share of about 40% of the national production [3]. There are three major cashew
64 regions within Nampula (North, Center and South).

65 2.2. Theoretical framework

66 Adoption describes the decision to use a new technology, practice or method by individual or
67 groups [12]. It can be viewed as individual or aggregated. Adoption at the individual level
68 reflects the decision of a farmer to integrate a new technology into his/she production
69 system. The aggregation or group adoption implies the diffusion of a new technology within a
70 region [12]. The focus of this study is the individual or household adoption. [13] defined

71 innovation as an idea, practice or object, perceived by **an individual** as new. It does not
72 matter whether the idea is new as measured by time or discovery. The newness of the idea
73 perceived by individual makes it an innovation. However, adoption is not a permanent
74 condition [14]. A farmer can decide to discontinue the use of a certain technology.

75 [12] argues that for divisible technologies, such as improved varieties or chemicals, it is
76 possible to assess the degree of use or intensity within a household. Intensity can be
77 measured as the number of hectares under an improved variety or the amount of inputs
78 applied per hectare. In this study, intensity of adoption is the number of grafted seedlings
79 planted annually and proportion of sprayed cashews.

80 The adoption of agricultural technology is expected to increase the farmers' productivity and
81 income. This means that farmers will select those technologies that maximize their perceived
82 utility. Therefore, when a farmer is confronted with two alternatives, he/she will compare their
83 utilities. If U_{i0} is the utility of farmer i derived from the use of traditional technology, and U_{i1} is
84 the utility from the adoption of new technology, it follows:

85
$$U_{i0} = \beta_{i0}X_{i0} + \varepsilon_{i0}$$

86
$$U_{i1} = \beta_{i1}X_{i1} + \varepsilon_{i1}$$

87 (1)

88 Where X is the farm specific function, β the parameter and ε the disturbance term.

89 The farmer i is likely to adopt the new technology if $U_{i1} > U_{i0}$ [15].

90 **2.3. Empirical model**

91 The literature suggests a variety of models for farmers' determinants of technology adoption.
92 Many researchers employed the dichotomous regressions to model determinants of
93 adoption, using Logit or Probit models [12, 16, 17]. However, these models explain only
94 whether the farmer uses or not the technology and not the degree of use [18]. Therefore, in

95 many cases, adoption cannot be explained adequately by the use of a dichotomous
96 qualitative variable [12].

97 For assessing intensity of adoption, Tobit model [19] has been widely employed. Different
98 authors applied the Tobit model for studying intensity of adoption of agricultural
99 technologies, for example [20, 21, 14, 22]. The major drawback of the Tobit model is to
100 assume that the decision to adopt and that of how much to adopt is made jointly. This
101 suggests that factors influencing the two decisions are the same. However, the decision to
102 adopt and the decision on the amount to adopt can be made separately [17]. In order to
103 allow a separate evaluation between adoption and intensity of use of TCP, we used the
104 double-hurdle model. This model was first proposed by [23] and it assumes that the
105 adoption decision and the intensity of adoption are determined independently. Recently,
106 double-hurdle model has been extensively applied to assess intensity of adoption, for
107 instance [24, 25, 17, 18, 26, 27, 28, 29]. In this model, the adoption decision may be
108 estimated by the Probit or Logit model [27], where all observations in the sample will be
109 used. This estimation is followed by the Truncated regression on the continuous positive
110 values [27]. The double-hurdle model has an adoption (D) equation:

111 $D_i = 1 \text{ if } D_i^* > 0$

112 $D_i = 0$ Otherwise

113 (2)

114 $D_i^* = \alpha'Z_i + \varepsilon_i,$

115 Where D^* is a latent variable that takes 1 if the farmer adopts the TCP, and zero otherwise.

116 Z is a vector of the household characteristics and α is the vector of parameters.

117 The intensity of adoption (Y) is represented by:

118 $Y_i = Y_i^* \text{ if } Y_i^* > 0 \text{ and } D_i^* = 1;$

119 $Y_i = 0, \text{ Otherwise}$

120 (3)

121 $Y_i = \beta'X_i + v_i$

122 Where Y_i is the observed number of grafted seedlings planted or proportion of the sprayed
123 cashews. X_i is a vector of household characteristic and β is the vector of parameters.

124 The error terms ε_i and v_i are assumed to be independent. The log-likelihood function for the
125 double hurdle model is:

126
$$\text{Log}L = \sum_0 \ln \left[1 - \Phi(\alpha Z_i') \left(\frac{\beta X_i'}{\sigma} \right) \right] + \sum_+ \ln \left[\Phi(\alpha Z_i') \frac{1}{\sigma} \phi \left(\frac{Y_i - \beta X_i'}{\sigma} \right) \right]$$

127 (4)

128 Where Φ and ϕ are the standard normal cumulative distribution function and density
129 function, respectively. Under the assumption of independence between ε_i and v_i , the
130 double-hurdle model is equivalent to a combination of Probit model and Truncated
131 regression.

132 **2.4. Data collection**

133 We used cross-sectional data collected in September 2016, using a structured questionnaire
134 at the household level. A multistage sampling technique was employed [30]. The first stage
135 involved the selection of three districts. Each district was purposively selected within each of
136 the three-cashew region in Nampula. This aimed at including districts that produce cashew
137 and benefit from activities of cashew technology promotion. The selected districts were
138 Angoche (South), Monapo (Central) and Erati (North). The second stage involved the village
139 selection within the districts, and three villages were randomly selected in each district. This
140 procedure consisted of assigning a number to each cashew village in the district and select
141 randomly three numbers, and then determine the village name the number belongs to [30].
142 Finally, 30 farmers' households were randomly selected in each village, following the

143 technique proposed by [30], making a total of 270 households to be interviewed.
144 Nevertheless, we were able to locate and interview only 258 households.

145 **2.5. Description of dependent variables**

146 In this study, two models are estimated, one for the seedling planting and another for
147 fungicide application. The dependent variable for adoption is dichotomous. Adopter is the
148 farmer who planted grafted seedling or applied fungicide in 2014/15. On the other hand, the
149 intensity of use indicates the number of grafted seedlings planted in 2014/15 or the
150 percentage of the sprayed cashews in 2014/15 out of the total owned.

151 **2.6. Description of explanatory variables and hypotheses**

152 Adoption literature provides long list of factors that may influence adoption of agricultural
153 technologies. For example, farmer's decision to use agricultural technologies are
154 hypothesized to be influenced by a combination effect of various factors such as household
155 characteristics, socio-economic and physical environment [24, 18, 31]. The explanatory
156 variables included in this study were mainly based on [12, 18, 31, 32]. We also considered
157 specific characteristics of the farming system in the study area². The variables hypothesized
158 to influence the adoption of TCP were grouped as: i) personal and household characteristics,
159 ii) economic and market access and iii) institutional and geographical factors.

160 **2.6.1. Personal and household characteristics variables**

161 Age of the household head determines whether a farmer is younger or elderly. Older farmers
162 are assumed to have gained knowledge and experience and assess more the attributes of a
163 technology than younger farmers [26, 32]. [33] argue that old farmers are more risk averse
164 and decrease interest in long term investment, while younger farmers are willing to try new
165 technologies. Education was measured as years of formal schooling attended. It is expected
166 to have positive effect on the adoption [24, 31, 26] because it increases farmer's ability to

² These variables are the output price, gender interaction with access to important resources and district index.

167 obtain relevant information for assessing technologies [14]. Farming experience was
168 measured as years of farming cashew. It increases the practical skills, hence increasing the
169 probability of adoption [31]. Gender is binary variable (male=1). It is expected to have
170 positive effect on the adoption. Generally, males have more access to information, education
171 and resources, which increase their adoption probability [26]. Training represents number of
172 days of training in cashew in 2014/15. It is expected to have positive effect because training
173 improves farmers' skills and knowledge.

174 **2.6.2. Economic and market access variables**

175 Access to credit is binary and refers to whether the household received credit in 2014/15.
176 Farmers who accessed credit may overcome financial constraints and purchase inputs [14].
177 Several authors found access to credit influencing positively adoption, including [16, 18, 27].
178 Family labor was measured in man equivalent. It is expected to have positive effect on
179 adoption. Land holding is an indicator of wealth and social status [14, 18]. Therefore, farmers
180 with large land are more likely to adopt technologies. It is measured in hectares. Output price
181 is an indicator for market access, and represents the relative profitability of a technology
182 [18]. It is expressed in US Dollar per kilogram. We hypothesized that price of cashew nut will
183 have positive effect on adoption. The interactions between gender and land and between
184 gender and family labor were defined to account for access to resources by gender. [34]
185 studied the effect of gender on adoption of maize varieties in Ghana and concluded that
186 there is no significant association between gender and adoption of agricultural technologies,
187 unless access to resources is correlated with gender. Therefore, gender on adoption should
188 be analyzed jointly with access to important resources.

189 **2.6.3. Institutional and geographical variables**

190 Access to extension services refers to whether the household was assisted by the cashew
191 extension officer in 2014/15. The extension assistance to farmers increases their
192 understanding of technology attributes and ensure their correct implementation. Given the

193 observed differences on socio-economic characteristics and development of cashew
194 production among the districts, we included in the model the district index for Angoche and
195 Erati. Monapo was used as benchmark.

196 3. RESULTS AND DISCUSSION

197 3.1. Descriptive statistics

198 Farmers' households were assessed with the objective of identifying factors determining
199 adoption of TCP in three districts of Nampula in Mozambique. About 27% of the surveyed
200 households planted grafted seedlings in 2014/15, with an intensity of seven seedlings
201 annually. On the other hand, 47% of the assessed households applied fungicide to cashews
202 against powdery mildew, with an intensity of 38% of the total owned cashews. [35],
203 investigating factors influencing adoption of cashew technologies in Tanzania, learned that
204 25% of the respondents adopted improved cashew planting materials. [36] found that 30% of
205 households planted grafted seedlings and 79.5% used sulfur for disease control in four
206 districts of the Southeast Tanzania. [37] while studying cashew disseminated technologies in
207 Mkinga district of Tanzania observed that 39% out 80 respondents planted improved cashew
208 varieties. Nevertheless, the adoption and intensity of use in our study area are still low,
209 especially because farmers are getting the technologies at a subsidized price.

210 Table 1 presents the mean comparison of continuous explanatory variables by adoption
211 group. Farmers who planted grafted seedlings and applied fungicide have higher education,
212 higher family labor, larger land and perceived higher output price in 2014/15. Moreover,
213 farmers who planted grafted seedlings had longer experience and training in farming
214 cashew.

215
216 **Table 1. Descriptive statistics of continuous variables by farmers' group**

Variable	Seedling planting			Fungicide application		
	Adopters	Non-adopters	t-test	Adopters	Non-adopters	t-test

	(70)	(188)		(120)	(138)	
Age	45.64	43.78	1.02	44.36	44.22	0.08
Education	4.56	3.38	2.91***	4.32	3.17	3.21***
Experience	20.66	17.64	1.88*	18.95	18.04	0.64
Training in cashew	2.90	0.41	4.25***	1.34	0.86	0.89
Family labor	2.72	2.37	2.27**	2.66	2.29	2.73***
Total land	4.83	3.42	2.89***	4.37	3.31	2.44**
Output price	33.94	29.72	3.27***	34.22	27.95	5.66***
Gender*land	4.71	3.24	2.96***	4.26	3.11	2.58**
Gender*labor	2.69	2.26	2.59**	2.61	2.17	3.00***

217 **Notes:** *, ** and *** denote statistically significant at 10%, 5% and 1% level, respectively.

218 **Source:** Own survey, 2016.

219 The results of Chi2 test for dummy explanatory variables showed significant difference of
 220 frequency between adopters and non-adopters in terms of access to extension and gender
 221 for both technologies, and access to credit for seedling planting (Table 2).

222 **Table 2. Descriptive statistics of dummy variables by farmers' group**

Variable	Character	Seedling planting			Fungicide application		
		Adopters	Non-adopters	χ^2 -Value	Adopters	Non-adopters	χ^2 -Value
		(70)	(188)		(120)	(138)	
Access to credit	Yes	6	4	5.68**	7	3	2.31
	No	64	184		113	135	
Access to extension	Yes	62	117	16.65***	101	78	23.09***
	No	8	71		19	60	
Gender	Male	69	175	2.99*	117	127	3.74*
	Female	1	13		3	11	
Angoche	Yes	44	38	42.78***	67	15	59.85***
	No	26	150		53	123	
Monapo	Yes	15	68	5.08**	32	51	3.11*
	No	55	120		88	87	
Erati	Yes	11	82	17.23***	21	72	33.47***
	No	59	106		99	66	

223 **Notes:** *, ** and *** denote statistically significant at 10%, 5% and 1% level, respectively.

224 **Source:** Own survey, 2016.

225 3.2. Empirical results

226 3.2.1. Determinants of adoption and intensity of use of grafted seedlings

227 The significant Wald chi-square value of 73.52 suggests that the explanatory variables jointly
228 explain the decision to use grafted seedlings. The truncated regression model is also
229 significant with test statistic for the likelihood of 91.66 (Table 3).

230 Age of the household head does not influence the decision to use grafted seedling.
231 However, it had positive effect on the intensity of planting. This means that the older the
232 farmer, greater is the number of seedlings they planted. [27] while studying socio-economic
233 determinants of intensity adoption of cocoa innovations in Ghana concluded that older
234 farmers will increase the intensity of a technology once they are convinced of its advantages.
235 [38, 39, 40] defend that elderly farmers tend to intensify adoption of technologies as result of
236 experience, higher capital accumulation and large family size. Large families are associated
237 with higher family labor.

238 **Table 3. Determinants of adoption and intensity of planting grafted seedlings**

Variable	Adoption (Probit)			Intensity (Truncated regression)		
	Coefficient	Robust Sta. Error	AME ^a	Coefficient	Robust Sta. Error	AME
Age	0.0031	0.0108	0.0008	0.5821**	0.2698	0.3598
Education	0.0728**	0.0337	0.0180	-0.0555	1.1888	-0.0343
Experience	-0.0379	0.0299	-0.0094	0.6822	0.9369	0.4217
Experience2	0.0010*	0.0005	0.0002	-0.0191	0.0164	-0.0118
Training in cashew	0.0435*	0.0230	0.0108	1.5978***	0.4831	0.9877
Access to credit	0.2213	0.4200	0.0549	6.3588	10.8770	3.9307
Family labor	-0.0050	0.0834	-0.0012	4.7163**	2.3289	2.9154
Total land	0.0541	0.0349	0.0134	0.8865	0.5491	0.5480
Output price	1.1965*	0.7219	0.2966	-1.7144	31.3938	-1.0597
Access to extension	0.5228**	0.2402	0.1296	0.7641	8.6836	0.4723

Angoche district	0.5523**	0.2479	0.1369	14.1409*	8.5425	8.7411
Erati district	-0.4893*	0.2508	-0.1213	20.1395*	11.5702	12.4491
Constant	-2.0903***	0.6038		-44.3072**	21.4023	0.3598
Wald chi2 (12)		73.52***			91.66***	
Log-Likelihood		-114.79			-278.61	
No. of observations		258			70	

Notes: *, ** and *** denote statistically significant at 10%, 5% and 1% level, respectively.

^a Average Marginal Effects

Source: Own survey, 2016.

The probability of using grafted seedlings is positively influenced by education of the household head. [35] found that a unit increase in education led to 26% increase in the log-odds of adopting cashew technologies in Tanzania. [29], who studied the adoption of maize varieties in Nigeria, explains that higher education influences farmers' attitudes and thoughts, making them more rational and able to analyze the benefits of a technology.

Farming experience had negative sign and insignificant for adoption. However, experience-squared was significant with positive coefficient. This implies that as the experience increases, the probability of adoption decreases until 19 years, from which starts increasing exponentially. This finding was also observed by [31] when studying adoption of tef technologies in Ethiopia. For [29] experience provides farmers with knowledge that increases their rationality in use of new technologies.

Training influenced positively both adoption and intensity. [36], when studying the adoption of cashew farming in Tanzania, concluded that training is a very important factor for adoption, since farmers need to understand and practice technologies before adopting.

Family labor had positive effect on the intensity of adoption. This suggests that grafted seedlings are labor intensive [24, 41]. Poor farmers' household rely on family labor for their farming operations [42]. This labor constraint can affect the crop productivity and return to the technology and discourage adoption. [35] observed similar effect of labor on cashew technologies.

261 Price of cashew nut had positive significant effect. [36] learned that when farm-gate prices of
262 raw cashew nut are low, farmers avoided buying seedlings in Tanzania. As highlighted by
263 [18], output price is the economic profitability easily perceived by farmers to their investment
264 on technologies. Therefore, technologies which are felt to be profitable, have higher
265 probability of being adopted.

266 Access to extension services had positive effect on adoption. Farmers who were visited by
267 extension officers are about 13% more likely to adopt grafted seedlings than their
268 counterparts. [35] found that access to extension services had 99% increase in the log-odds
269 of adoption of cashew technologies in Tanzania. This effect was expected since extension
270 services disseminate information, knowledge and practical skills for agricultural technologies.
271 In Mozambique, many farmers have limited access to extension services, thus lowering their
272 probability to adopt technologies. [4] observed that cashew farmers in the Northern
273 Mozambique did not know the advantages of grafted seedlings, thus not willing to buy.

274 Farmers in different districts used grafted seedlings at different degrees. In Angoche they
275 are about 14% more likely to adopt than in Monapo and planted about 9 seedlings more
276 compared to Monapo. While farmers in Erati are 12% less likely to plant grafted seedlings
277 compared to Monapo. Nevertheless, the farmers who planted seedlings in Erati, planted 12
278 seedlings more than their counterparts in Monapo.

279 Higher adoption in Angoche can be explained by availability of seedlings, since there is a
280 nursery, which enables farmers to get seedlings on time. [36] argues that unavailability of
281 technologies near the farmers affects the adoption, since it becomes more expensive and
282 time-consuming for travelling to nearby villages. In Angoche, Monapo and Erati, 66%, 92%
283 and 95%, respectively of households who did not plant grafted seedlings, reported as first
284 reason unavailability of seedlings at the planting time. Higher planting intensity in Erati than
285 in Monapo may suggest that farmers with better financial resources in this district are able to

286 afford higher transportation cost and get seedlings from outside the district. And in order to
287 make their investment more profitable, they tend to acquire larger quantities of seedlings.

288 3.2.2. Determinants of adoption and intensity of use of fungicide

289 Table 4 presents the estimation results for adoption and intensity of use of fungicide. The
290 results of the Probit model show that the Wald chi-square of 96.28 is significant at 1% level.
291 This implies that the model is fitted and the variables included, collectively explain fungicide
292 application. The truncated regression is also significant with Wald chi-square value of 48.73.
293 Age of household head influenced negatively the intensity of fungicide application. This
294 suggests that younger farmers are more likely to intensify the use of fungicide. [43] found
295 that adoption of genetically modified maize varieties in Indiana increases with age among
296 young farmers as they gained experience and increase their human capital, then it declines
297 with age close to retirement. [33] highlighted that young farmers are less risk averse and
298 may easily adopt new technologies. [44] also observed age affecting negatively the intensity
299 of adoption of improved rice varieties in Nigeria.

300 **Table 4. Determinants of adoption and intensity of use of fungicide**

Variable	Adoption (Probit)			Intensity (Truncated regression)		
	Coefficient	Robust Sta. Error	AME ^a	Coefficient	Robust Sta. Error	AME
Age	-0.0041	0.0108	-0.0011	-0.4633*	0.2524	-0.4585
Education	0.0631*	0.0344	0.0174	-1.3456	0.8853	-1.3317
Experience	0.0074	0.0115	0.0020	-0.0756	0.2441	-0.0748
Access to credit	-0.1859	0.2765	-0.0513	-0.0938	3.9689	-0.0928
Family labor	0.1081	0.1307	0.0298	3.6603**	1.6739	3.6227
Total land	-0.1252	0.4170	-0.0345	-3.7869	10.9405	-3.7479
Output price	2.1611***	0.7252	0.5961	-10.7861	19.8408	-10.6751
Access to extension	0.5929***	0.2004	0.1636	12.6490	7.7383	12.5188
Angoche district	0.8619***	0.2520	0.2377	5.7637	6.2290	5.7044
Erati district	-0.6592***	0.2212	-0.1818	1.0002	8.2653	0.9899
Gender*labor	0.1719	0.2767	0.0474	0.3359	3.8697	0.3324
Gender*land	-0.0358	0.1309	-0.0099	-3.0068*	1.6763	-2.9758
Constant	-1.9138***	0.5535		97.4670***	13.7613	

Wald chi2 (12)	96.28***	48.73***
Log-Likelihood	-127.23	-557.51
No. of observations	258	120

Notes: *, ** and *** denote statistically significant at 10%, 5% and 1% level, respectively.

^a Average Marginal Effects

Source: Own survey, 2016.

As expected, formal education positively influenced the use of fungicide, but not its intensity. [35] observed similar effect of education on adoption of cashew production technologies in Tanzania. Higher education of farmers increases their ability to obtain and use information on technologies [32]. [27] found that primary and tertiary education influenced the adoption of cocoa technologies in Ghana.

Availability of family labor had positive and significant effect on the intensity of use. Cashew farmers sprayed about 4% more at each man equivalent increment. Although the use of fungicide does not require direct application of labor, other complementary activities does. These activities include weeding, pruning and collection of cashew nut, which in case of not being performed properly on time may affect the return on fungicide investment.

The output price had positive effect on the adoption of fungicide. This implies that farmers who received higher prices were more motivated to use fungicides. [45], who investigated the constraints of farmers in cashew production in Nigeria, defend that lower cashew nut price does not encourage farmers to invest in inputs, because it increases uncertainty on the expected return for the crop. [46], who studied factors for adoption of technology for cashew production in Brazil, also observed positive effect of cashew nut price on adoption.

Access to extension services determined positively the adoption of fungicide. Farmers who accessed extension services were 16% more likely to use fungicide than their counterparts.

Extension officers provide relevant information on cashew spraying and connect farmers to service suppliers. [47] found extension services influencing positively adoption of improved onion varieties in Bangladesh and argue that new varieties or practices require more

325 extension assistance than the traditional ones, thus, farmers who access extension services
326 are more likely to adopt.

327 Farmers in Angoche were 24% more likely to use fungicide compared to farmers in Monapo.
328 While farmers in Erati had 18% probability less to adopt than in Monapo. This can be
329 explained by the existence of more human resources for the extension services and
330 community cashew promoters in Angoche. From our observations, Erati is characterized by
331 poor infrastructures and relative remoteness as compared to the two other districts, which
332 can imply higher transportation cost, thus the middlemen willing to pay low farm-gate price.

333 Interaction between gender and land was statistically associated with intensity of fungicide
334 application. The negative coefficient suggests that females with more land are more likely to
335 intensify the use of fungicide. This confirms the hypothesis that resource allocation on
336 gender can influence the adoption of technologies and that females are land constrained.

337 **4. CONCLUSION**

338 We identified factors determining the probability and intensity of adoption of TCP in
339 Nampula, Mozambique. The decision to use the TCP and how much to use are influenced
340 by different factors.

341 The adoption of grafted seedlings was determined by formal education, farming experience,
342 training in cashew, price of cashew nut and access to extension services. While the intensity
343 of planting was influenced by age, training in cashew and availability of family labor.
344 Adoption and intensity of seedling planting was higher in the district of Angoche. This implies
345 that cashew famers in Angoche have realized the importance of TCP for increasing
346 productivity. Grafted seedling availability at farmers' village is among the major determinants
347 for adoption. INCAJU should increase seedling availability at the village level by involving
348 and supporting private seedling producers at the village level and enhance the existing

349 cashew stakeholders. Another strategy should be to establish a public nursery³ in Erati,
350 which would also provide seedlings to the neighboring districts of Nacaroa and Chiure. The
351 use of fungicide was influenced by education, price of cashew nut and access to extension
352 services. While the intensity of use was association with age, availability of family labor and
353 interaction between gender and land holding. Similar to seedling planting, many farmers in
354 Angoche and a few in Erati used fungicide.

355 Access to extension services was found to be one of the most powerful factor for adoption of
356 TCP. Extension assistance increases awareness of farmers on agricultural technologies and
357 their practical skills. Therefore, the government should strengthen the cashew extension in
358 human capital and means of transportation and communication. In this regard, especial
359 attention should be given to the districts of Erati and Monapo. When promoting TCP, farmers
360 with higher education level should be used as lead farmers for influencing others to adopt.
361 Minimum price policies should be adopted and its implementation must be monitored to
362 ensure that farmers get the expected return to technology investment and encourage them
363 to use new technologies. Age of the household and family labor availability were the
364 common factors for intensifying the use of both technologies. Elderly farmers intensified
365 more seedling planting, while the younger ones intensified the use of fungicide. Land
366 ownership among women increases the intensity of fungicide plan application.

367 **COMPETING INTERESTS**

368 No competing interest under this study.

369 **REFERENCES**

- 370 1. Uaciquete A, Fernando A. Status of Cashew Subsector in Mozambique, Current and
371 Future Strategies. Proceedings on Second International Cashew Conference.
372 Kampala. 2010:192-197.

³ The public cashew nurseries are not new strategies in Nampula. They were already established in the districts of Angoche, Meconta and Mogovolas.

- 373 2. WONGNA A. Analysis of Factors Affecting the Production of Cashew in Wench
374 Municipality, Ghana. The Journal of Agricultural Sciences. 2013;8(1):8-16.
- 375 3. MIC (Ministry of Industry and Commerce). Study of Cashew Nut with Added Value for
376 Export. Maputo: MIC; 2010.
- 377 4. Kanji N, Vijfhuizen C, Artur L, Braga C. Liberalization, Gender and Livelihoods:
378 Cashew Nuts in Mozambique. Maputo: Eduardo Mondlane University; 2004.
- 379 5. INCAJU (Cashew Promotion Institute). Cashew Sub-sector in Mozambique: Evolution
380 and Perspectives. Proceedings on the African Cashew Alliance. Maputo; 2007.
- 381 6. Uaciquete A. Characterization, Epidemiology and Control Strategies for the new
382 Anthracnose Pathogen on Cashew nut in Mozambique. PhD Dissertation. Pretoria:
383 University of Pretoria; 2013.
- 384 7. FAO (Food and Agriculture Organization). Food and Agriculture Data. Accessed 5
385 January 2017. Available: <http://www.fao.org/faostat/en/#data/QC>.
- 386 8. INCAJU (Cashew Promotion Institute). Program for Integrated Management,
387 Production and Distribution of Seedlings: Principles and Prices to be Observed in the
388 Economic Year 2017. Maputo: INCAJU; 2017.
- 389 9. MINAG (Ministry of Agriculture). National Agricultural Survey. Maputo: MINAG; 2012.
- 390 10. INE (National Statistics Institute). Agrarian Census CAP 2009-2010. Maputo: INE;
391 2011.
- 392 11. IIAM (Institute of Agricultural Research of Mozambique). Agro-ecological zones.
393 Accessed 6 January 2017. Available:
394 [http://www.iiam.gov.mz/index.php?option=com_content&view=article&id=162:regiao-](http://www.iiam.gov.mz/index.php?option=com_content&view=article&id=162:regiao-norte&catid=53:zonas-agroecologicas)
395 [norte&catid=53:zonas-agroecologicas](http://www.iiam.gov.mz/index.php?option=com_content&view=article&id=162:regiao-norte&catid=53:zonas-agroecologicas).

- 396 12. Feder G, Just RE, Ziberman D. Adoption of Agricultural Innovations in Developing
397 Countries: A Survey. *Economic Development and Cultural Change*. 1985;255-298.
- 398 13. Rogers ER. *Diffusion of Innovations*. 3rd ed. New York: The Free Press; 1983.
- 399 14. Giziew A. *Determinants of Adoption and Its Intensity on Agricultural Technologies*.
400 Germany: VDW Verlag Dr. Muller; 2010.
- 401 15. Nahuelhual L, Engler MA, Carrilo B, Moreira V, Castro I. Adoption of Cleaner
402 Production Practices by Dairy Farmers in Southern Chile. *Ciencia e Investigacion*
403 *Agraria*. 2009;36(1):97-106.
- 404 16. Uaiene RN, Ardnt C, Masters WA. *Determinants of Agricultural Technology Adoption*
405 *in Mozambique*. Discussion paper 67E. Ministry of Planning and Development.
406 Maputo; 2009.
- 407 17. Awotide BA, Abdoulaye T, Alene A, Manyong VM. Assessing the Extent and
408 Determinants of Adoption of Improved Cassava Varieties in South-Western Nigeria,
409 *Journal of Development and Agricultural Economics*. 2014;6(9):376-385.
- 410 18. Beshir H. Factors Affecting the Adoption and Intensity of Use of Improved Forages in
411 North East Highlands of Ethiopia. *American Journal of Experimental Agriculture*.
412 2014;4(1):12-27.
- 413 19. Tobin J. Estimation of Relationships for Limited Dependent Variables. *Econometrica*.
414 1958;26(1):24-36.
- 415 20. Oladele OI. A Tobit Analysis of Propensity to Discontinue Adoption of Agricultural
416 Technology Among Farmers in Southwestern Nigeria. *Journal of Central European*
417 *Agriculture*. 2005;6(3):249-254.
- 418 21. Chukwuji CO, Ogisi OD. A Tobit Analysis of Fertilizers Adoption by Smallholder
419 Cassava Farmers in Delta State, Nigeria. *Agriculture Journal*. 2006;1(4):240-248.

- 420 22. Asfaw S, Shiferaw B, Simtowe F, Hagos M. Agricultural Technology Adoption, Seed
421 Access Constraints and Commercialization in Ethiopia. *Journal of Development and*
422 *Agricultural Economics*. 2011;3(9):436-447.
- 423 23. Cragg JG. Some Statistical Models for Limited Dependent Variables with Application
424 to the Demand of Durable Goods. *Econometrica*. 1971;39(5):829-844.
- 425 24. Beshir H, Emanu B, Kassa B, Haja J. Determinants of Chemical Fertilizers
426 Technology Adoption in North Eastern Highlands of Ethiopia: The Double-hurdle
427 Approach. *Journal of Research in Economics and International Finance*.
428 2012;1(2):39-49.
- 429 25. Mal P, Anik AR, Bauer S, Schmitz M. Bt Cotton Adoption: A Double-hurdle Approach
430 for North Indian. *AgBioForum*. 2012;15(3):294-302.
- 431 26. Martey E., Wiredu AN, Etwire PM, Fosu M, Buah SSJ, Bidzakin J, et al. Fertilizer
432 Adoption and Use Intensity Among Smallholder Farmers in Northern Ghana: A Case
433 Study of the AGRA Soil Health Project. *Sustainable Agriculture Research*.
434 2014;3(1):24-36.
- 435 27. Darko EO. Socio-Economic Determinants of Intensity of Adoption of Cocoa Research
436 Innovation in Ghana. *International Journal of African and Asian Studies*. 2015;12:29-
437 40.
- 438 28. Ghimire R, Huang W, Poudel MP. Adoption Intensity of Agricultural Technology:
439 Empirical Evidence from Smallholder Maize Farmers in Nepal. *International Journal*
440 *of Agriculture Innovations and Research*. 2015; 4(1):139-146.
- 441 29. Kuti WI. Determinants of Adoption of Improved Maize Varieties in Osun State,
442 Nigeria. *International Journal of Agricultural Economics and Extension*.
443 2015;3(2):115-121.

- 444 30. Stopher P. Collecting, Managing, and Assessing Data Using Sample Surveys. New
445 York: Cambridge University Press; 2012.
- 446 31. Weyessa BG. A Double-Hurdle Approach to Modeling of Improved Tef Technologies
447 Adoption and Intensity Use in Case of Diga District of East Wollega Zone. Global
448 Journal of Environment Research. 2014;8(3):41-49.
- 449 32. Mwangi M, Kariuki S. Factors Determining Adoption of New Agricultural Technology
450 by Smallholder Farmers in Developing Countries. Journal of Economics and
451 Sustainable Development. 2015;6(5):208-216.
- 452 33. Adesina AA, Zinnah MM. Technology Characteristics, Farmers' Perceptions and
453 Adoption Decisions: A Tobit Model Application in Sierra Leone. Agricultural
454 Economics. 1993;9:297-311.
- 455 34. Doss CR, Morris ML. How does Gender Affect Adoption of Agricultural Innovations?
456 The Case of Improved Maize Technology in Ghana. Agricultural Economics.
457 2001;25(1):27-39.
- 458 35. Kidunda BR, Kasunga LJ, Magani SF, Mwakanyamale DF. Adoption of Cashew
459 Production Technologies by farmers in the Southeastern Tanzania. Proceedings of
460 International Conference on Food and Agricultural Sciences. Singapore. LACSIT
461 Press. 2013;55(18):94-99.
- 462 36. Mshana M. Adoption of Cashew Nut Farming Technologies in South-Eastern
463 Tanzania. Proceedings of Second International Cashew Conference. Kampala.
464 2010:109-111.
- 465 37. Ibrahim G. Disseminated Cashew Nut Production Technologies and their Effect to
466 Cashew Nut Production in Mkinga District, Tanzania. MSc Thesis. Morogoro:
467 Sokoine University of Agriculture; 2015.

- 468 38. Gebru A. The Determinants of Modern Agricultural Inputs Adoption and their
469 Productivity in Ethiopia. Addis Ababa: Addis Ababa University; 2006.
- 470 39. Nhamachena C, Hassan R. Micro-Level Analysis of Farmers' Adaptation to Climate
471 Change in Southern Africa. IFPRI Discussion paper 00714. Washington, DC; 2007.
- 472 40. Regassa AE. Determinants of Agro Pastoralists' Participation in Irrigation Scheme:
473 The Case of Fentalle Agro Pastoral District, Oromia Regional State, Ethiopia.
474 International Journal of Agricultural Research, Innovation and Technology.
475 2015;5(2):44-50.
- 476 41. Solomon T, Tessema A, Bekele A. Adoption of Improved Wheat Varieties in Robe
477 and DigeluTijo Districts of Arsi Zone in Oromia Region, Ethiopia: A Double-hurdle
478 Approach. African Journal of Agricultural Research. 2014;9(51):3692-3703.
- 479 42. Rehman A, Jingdong L, Khatoon R, Hussain I. Modern Agricultural Technology
480 Adoption, its Importance, Role and Usage for the Improvement of Agriculture.
481 American-Eurasian Journal of Agricultural & Environmental Sciences.
482 2016;16(2):284-288.
- 483 43. Alexander CE, Mellor TV. Determinants of Corn Rootworm Resistant Corn Adoption
484 in Indiana. AgBioForum. 2005;8(4):197-204.
- 485 44. Awotide BA, Karimov AA, Diague A. Agricultural Technology Adoption,
486 Commercialization and Smallholder Rice Farmers' Welfare in Rural Nigeria.
487 Agricultural and Food Economics. 2016;4(1):1-24
- 488 45. Uwagboe EO, Adeogun SO, Odebode SO. Constraints of Farmers in Cashew
489 Production: A Case Study of Orire L. G. A. of Oyo State, Nigeria. ARPN Journal of
490 Agricultural and Biological Sciences. 2010;5(4): 27-31.

491 46. Lima SS, Khan AS, Lima PS, Leite LAS, Mattos, ALA. Technological Level and
492 Decision Factors for Technology Adoption in Cashew Production in Ceará. Journal of
493 Economics and Agro-business. 2010; 8 (1): 121-145. English.

494 47. Anik AR, Salam MA. Determinants of Adoption of Improved Onion Variety in
495 Bangladesh. Journal of Agriculture and Environment for International Development.
496 2015;109(1):71-88.

497

UNDER PEER REVIEW