

1 *The Dynamics of Household Labor allocation to Biogas production, Farm and Non-farm*
2 *activities in Central Uganda*

3 **Abstract**

4 Biogas is a sustainable energy that contributes to improved health and provides socio-economic
5 benefits. However, biogas production has an impact on an essential household resource; labor.
6 Therefore, households need to efficiently allocate labor to activities on the farm, off-farm and for
7 biogas production. There is little empirical evidence on the factors influencing labor allocation
8 within farm households, thus limiting biogas technology promoters from creating a favorable
9 environment for uptake. This study fills this gap. Data were obtained from households with biogas
10 digesters in central Uganda through a snow-balling sampling technique. A household model was
11 used, and labor share equations were estimated by a Seemingly Unrelated Regression model. Own
12 activity labor returns showed a positive relationship to the respective labor share, but cross-labor
13 returns were negatively related. Female-headed households were more likely to allocate labor to
14 biogas activities. Distance to water source had a negative impact on labor allocation to biogas
15 activities, while the number of cattle owned by the household had a positive impact. Age of the
16 household head and household size had a positive impact on labor allocation to non-farm activities.
17 Household labor should be critically analyzed before investing in biogas digesters to increase the
18 success of the technology.

19 **Keywords:** Biogas technology, labor, resources, up-take

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26 **1. Introduction**

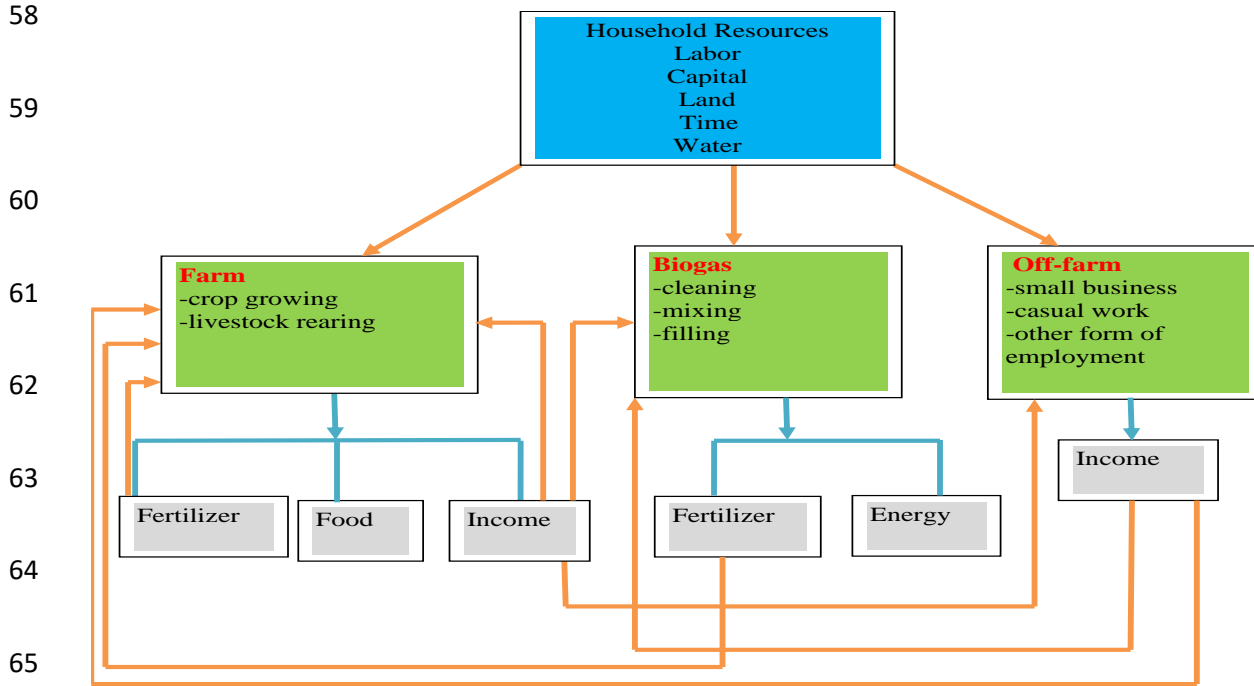
27 Over 80% of African households depend on traditional biomass fuel to satisfy their daily cooking
28 needs (Morrissey, 2017). The high rate of deforestation in Uganda has led to increased cost of
29 biomass fuels, which together with increasing public awareness of climate change, has triggered a
30 switch to more sustainable energy sources (Dhillion *et al.*, 2003). Anaerobic digestion of organic
31 wastes to produce biogas has been cited as one possible source of sustainable energy (Omar, 2015).
32 However, biogas production competes with other livelihood activities (farm and non-farm) for
33 labor, water and capital (Mwirigi *et al.*, 2014; Kileo and Akyoo, 2014). This study focuses on the
34 impact of biogas production on household labor allocation.

35 Due to constrained household resources, adoption of intensive technologies often requires a trade-
36 off of resources from one activity to another (Ndandula, 2011). Labor is an important resource
37 available to farmers (Sikei *et al.*, 2009), and they channel it towards activities that bring more
38 returns while not hindering other imperative activities. In a typical farm household, labor is
39 required for tasks relating to biogas production, farm and non-farm activities. Tasks required for
40 biogas production include collecting water, mixing feedstock and feeding the digester daily (Tucho
41 *et al.*, 2016). Farm related activities mainly include crop cultivation and animal rearing, while non-
42 farm activities may include small side businesses (McCullough, 2017). Other resources used in
43 biogas production include water (Mwirigi *et al.*, 2014), animal wastes and crop residues (Patowary
44 *et al.*, 2016). Off-farm wastes, such as blood and rumen content from slaughterhouses, can also be
45 used to produce biogas, the anaerobic process required to produce biogas potentially reducing the
46 hazardous impact of pathogens in the environment (Abdeshahian *et al.*, 2016).

47 Anaerobic digestion has two main products; fuel and slurry (Arsova, 2010). The slurry can be used
48 on the farm as a fertilizer, while biogas is used by the household for cooking and lighting, both in
49 the home and in animal housing (Arsova, 2010). Sales from crops and animals provide income to
50 the household, which can also be used for off-farm purchases, feeding into both the household and
51 the non-farm sector. Income from non-farm activities feeds back into the household, where it could
52 be used to purchase more animals or do repairs on the biogas digester. Though not a focus in this
53 study, land is also required for setting up the biogas plant, crop cultivation, animal grazing and
54 animal structures. With this interdependence of resources and activities, farm households need to

55 make decisions on where to allocate their precious labor resource and how much of it should be
56 given to each activity.

57 **Fig. 1: Inter-relationship between farm, biogas and non-farm activities**



66 Households aim to maximize utility, and so allocate labor depending on the level of utility derived
67 from each activity. However, there is little empirical evidence on the determinants of farm
68 household labor allocation to biogas production, which makes it difficult for biogas technology
69 promoters to enhance uptake of the technology. This study examines the factors influencing
70 household labor allocation to farm, biogas production and non-farm activities.

71 **2. Materials and Methods**

72 **2.1. Data collection**

73 A household survey was conducted in Mpigi and Luwero districts of central Uganda in September
74 2014. Mpigi district is located in the West of Kampala, Uganda's capital city, whereas Luwero
75 district is located in the North West of Kampala. Mpigi covers about 3,714 square kilometers while
76 Luwero covers about 2,577.49 square kilometers. The total population of Luwero district was

77 estimated at 456,958 and 250,548 for Mpigi district in 2014 (UBOS, 2017). Farming is the major
78 livelihood activity in both districts and is dominated by small holder farmers. Firewood and
79 charcoal are mainly used for cooking, while kerosene and solar energy are used for lighting. These
80 districts were purposively selected because they have been targeted by NGOs promoting biogas
81 technology. The households in Mpigi had a good number of functioning digesters, whereas most
82 of the digesters in Luwero district households were non-functional. Therefore, this provided a
83 strong basis for comparison of resource flows. A snow-balling method of sampling was used,
84 where one respondent suggested another person who uses biogas technology to be included in the
85 survey. Face to face interviews were guided by pre-tested questionnaires and this was followed by
86 intense discussions and field observation. A total of 41 respondents who were currently using and
87 38 who had previously used biogas technology were interviewed.

88 **2.2. Data analysis**

89 Data was entered in SPSS (Statistical Package for Social Scientists) version 18 and later analyzed
90 in STATA version 13. The study involved both qualitative and quantitative methods of analysis.
91 Households were grouped based on their biogas digester status (functional, non-functional or
92 without) and level of resource endowment. Means, standard deviations and independent t-tests
93 were used to statistically compare the different households. In investigating the factors influencing
94 labor allocation to farm, biogas and non-farm activities, this study drew from economic theory of
95 farm households (Singh *et al.*, 1986). The household model was used because it explicitly accounts
96 for the fact that many low-income farm households are both producers and consumers of farm and
97 other goods, and the markets for key factors and products are weak in rural areas of developing
98 countries (Sikei *et al.*, 2009). This means that specification of the production and consumption of
99 subsistence households in most developing countries is interdependent and non-separable. The
100 assumption of interdependence and thus non-separability of production and consumption imply
101 that household resource allocation is decided simultaneously rather than recursively (Heltberg *et*
102 *al.*, 2000). The joint production and consumption of agricultural commodities and biogas products
103 demands the use of a non-separable household model rather than a pure demand model (Singh *et*
104 *al.*, 1986).

105

106 2.3. Conceptual framework and empirical model

107 The model presented below assumes that members of the households are engaged in farm
108 activities, biogas production activities and non-farm activities. The equations were adopted from
109 Chang *et al.* (2012) in their study of labor supply, income and welfare of the farm household. The
110 household maximizes utility by choosing labor allocation to specific activities, consumption and
111 inputs. Therefore, the household solves,

$$112 \quad \max (U) = U(C_j, N; H) \quad (1)$$

113 where U is the utility, dependent on consumption of commodities, C_j (where $j =$ agricultural
114 products (a), biogas products (b), or non-farm goods (o)), leisure activities, N , and H household
115 characteristics that influence preferences. Household leisure, N , is not modeled since the leisure-
116 labor margin in most rural households in Sub-Saharan Africa is negligible (Sikei *et al.*, 2009).

117 The household maximizes utility subject to the production function for agricultural commodities,
118 biogas products, and non-farm goods. Production for agricultural commodities, Q_a , is assumed to
119 be a function of labor, L_a , purchased inputs such as fertilizer, X , and the household's land
120 endowment, A_0 ,

$$121 \quad Q_a = Q_a(L_a, X, A_0) . \quad (2)$$

122 The values for L_a , X and A_0 were obtained from the household survey.

123 Households use their own labor but may also hire-in some labor for agricultural production. Hired
124 labor and household labor are assumed to be substitutable. Households are also assumed to be risk
125 averse.

126 The production function for biogas products, Q_b , is assumed to be a function of labor used in
127 production of biogas, L_b , the distance to the nearest water source, W , and the number of cattle
128 owned by the household, K ,

$$129 \quad Q_b = Q_b(L_b, W, K). \quad (3)$$

130 The values for L_b , W and K were obtained from the household survey.

131 The production function for the non-farm goods, Q_o , is assumed to be only dependent on labor
132 used in production L_o ,

$$133 \quad Q_o = Q_o(L_o). \quad (4)$$

134 The values for L_o was obtained from the household survey.

135 The maximization of utility is solved using the method of Lagrange multipliers, constrained by
136 household budget (Y).

137 Households are assumed to participate in competitive markets for agricultural products where they
138 can buy and sell at a market price (P_j) which is assumed to be exogenous. Farm inputs (X) are
139 assumed to be bought but not sold. Households may also buy and/or sell labor, L_v , at a market
140 wage rate, v . The household budget constraint, Y , is therefore defined as

$$141 \quad Y = \sum_j [(P_j Q_j - P_j C_j)] - P_x X + v L_v \quad (5)$$

142 where Q_j is the production function for agricultural products ($j = a$), biogas products ($j = b$), or
143 non-farm goods ($j = o$), and P_x is the market price for farm inputs.

144 The labor market is very small, so $v L_v$ is assumed to be negligible. Therefore, it is not necessary
145 to determine the value of v .

146 Time available to the household, T , constrains available labor,

$$147 \quad T - N = \sum_j L_j. \quad (6)$$

148 The Lagrangian for the household utility maximization is therefore

$$\begin{aligned}
149 \quad L &= U \left(C_j, T - \sum_j L_j ; H \right) \\
150 \quad &+ \lambda \{ [P_a Q_a(L_a, X, A_0) - P_a C_a] + [P_b Q_b(L_b, W, K) - P_b C_b] + [P_o Q_o(L_o) - P_o C_o] \\
151 \quad &- P_x X \} \tag{7}
\end{aligned}$$

152 where L is the Langrange function, and λ is the Lagrange multiplier.

153 After re-arranging the first order condition, the following expressions are derived;

$$154 \quad dU(.) / dC_a = \lambda P_a \tag{8}$$

$$155 \quad dU(.) / dC_b = \lambda P_b \tag{9}$$

$$156 \quad dU(.) / dC_o = \lambda P_o \tag{10}$$

$$157 \quad dU(.) / dN = \lambda P_a dQ_a(.) / dL_a \tag{11}$$

$$158 \quad dU(.) / dN = \lambda P_b dQ_b(.) / dL_b \tag{12}$$

$$159 \quad dU(.) / dN = \lambda P_o dQ_o(.) / dL_o \tag{13}$$

$$160 \quad P_a dQ_a / dX = P_x \tag{14}$$

161 where $U(.)$ denotes the household utility function

162 Equations 8-14 indicate that, at the optimum, households allocate labor across activities so as to
163 equalize the marginal value of household leisure with that of the time spent on each productive
164 activity. In addition, at equilibrium, the ratios of marginal products of $C_a, C_b,$ and $C_o,$ are
165 equivalent to their price ratios. Expressions for labor supply, input demand and commodity
166 demand can be derived as functions of all exogenous variables; P_j, H, A_0, W, K, T

167 In constructing the empirical model, labor shares were taken as dependent variables. The model is
168 a system of three jointly estimated labor share equations. One equation is for biogas activities, the
169 second is for agriculture activities and the third is for non-farm activities. Each labor share is a
170 function of selected household characteristics. The model takes the following form, (Shively *et al.*,
171 2005);

$$172 \quad L_{ij} = \alpha_i + \sum \beta_{ij} \log(P_j) + \theta_i A + \eta_i S + \gamma_i E + \mu_i A_0 + \Psi_i n + \delta_i W + \phi_i K + \varepsilon_i \quad (15)$$

173 where subscript i represents the individual household and j represents different activities, L_{ij} is the
174 labor share to each activity (hours), P_j is the labor return from each activity (Uganda shillings), A
175 is the age of household head (years), E is the education of household head (years in school), A_0 is
176 the size of land holding (ha), S is the sex of the household head, n is household size (number of
177 household members available for labor), W is the distance to water source (m), K is the number of
178 cattle owned by the household, ε_i is an error term, and $\alpha_i, \beta_{ij}, \theta_i, \eta_i, \gamma_i, \mu_i, \Psi_i, \delta_i$ and ϕ_i are
179 coefficients that reflect the importance of each household characteristic.

180 The age of household head (A), education (E), size of land holding (A_0), sex of household head
181 (S), household size (n), distance to water source (W) and number of cattle owned (K) were obtained
182 directly from the household survey.

183 In this study, the error terms across the equations in the system are correlated since the same
184 explanatory variables and unobserved characteristics may influence the different equations.
185 Therefore, estimating the individual equations using ordinary least-squares yields biased and
186 inconsistent estimates (Woodridge, 2002). We therefore adopted the Seemingly Unrelated
187 Regression model proposed by Zellner (1962) since it accounts for the cross-equation correlations.
188 The merit of the Seemingly Unrelated Regression model is that it allows the estimation of the
189 system of equations simultaneously, thereby controlling correlation across the error terms in the
190 different equations.

191 **3. Results and discussion**

192 **3.1. Characterization of farm households**

193 Households were categorized in terms of the status of their biogas digesters; these included
 194 functional digester status and non-functional digester status. A total of 41 households had
 195 functional biogas digesters and 38 households had non-functional digesters. Results showed that
 196 men were the heads in the majority of households in both categories (71% for households with
 197 functioning biogas digesters and 63% for households with non-functioning biogas digesters).
 198 Household heads tend to have better understanding of resources in the household and they are
 199 mostly the final decision makers (UBOS, 2010). Arora and Rada (2013) asserted that one aspect
 200 of gender relations within rural households is that women do not control income generated through
 201 their labor, and so are resource constrained and income poor. Not having such power in the
 202 household limits the involvement of women into investment decisions regarding biogas
 203 technology. This was also highlighted by Mwirigi *et al.* (2014), who stated that the main causes of
 204 limited, little or no involvement of women in the decision for procurement of energy sources was
 205 low levels of income and control over productive resources.

206 The average age of household heads was 54.5 and 48.8 years for households with functional and
 207 non-functional digesters respectively. The high average age of the heads of households owning a
 208 biogas digester is because older household heads tend to have more resource endowment (in terms
 209 of livestock and income) compared to younger household heads, and so there is an automatic bias
 210 towards biogas digesters being installed in older headed households.

211 The average number of years of schooling was 10 for households with functional digesters and 6
 212 for those with non-functional digesters as shown in Table 1.

213 **Table 1: Socio-economic characteristics of households with functional digesters and non-**
 214 **functional digesters**

	Non-functional digester		Functional digester	
	Mean	Std deviation	Mean	Std deviation
Age-household head (years)	49	13	55	12
Education of household head (years)	7	3	11	3
Household size	6	3	7	3
Total land (hectares)	2	1.5	3	3.3
Crop land (hectares)	1.2	0.9	1.1	1
Grazing land (hectares)	0.1	0.2	0.3	0.6
Biogas land (sq meters)	5	13	10	47

215 3.2. Inventory of household resources

216 The main household resources were land, labor, livestock and crops. The average resource
217 ownership is summarized in Table 2. There was a significant statistical difference in the number
218 of cattle and pigs owned by households with functional digesters compared to those with non-
219 functional digesters.

220 **Table 2: Household resource endowment by households with and without digesters**

Household resource type	Average for functional digesters (n=41)	Average for non-functional digesters (n=38)	Mean difference for functional vs. non-functional
Land (hectares)	2.6	2.1	0.5
Labor (numbers ¹)	6.2	4.2	2.0***
Cattle (numbers)	3.9	1.5	2.5***
Pigs (numbers)	7.3	2.9	4.3**
Goats (numbers)	1.9	1.4	0.5

221 ***, **, * Significant at 1%, 5% and 10% respectively numbers¹, number of adult equivalent in the
222 household

223 Households with functional digesters had more cattle and pigs compared to their counterparts with
224 non-functional digesters. This emphasizes the role of feedstock in adoption of biogas technology.
225 Other studies, such as Pandey *et al.* (2007), have noted that cattle and pigs are the major sources
226 of feedstock for a biogas digester. Christiansen and Herltberg (2012) concluded that the suspension
227 of biogas in China was due to lack of or too few animals at some point of the year.

228 3.3. Determinants of household labor allocation

229 Table 3 shows the summary statistics of the returns from each activity, while table 4 shows factors
230 that influence household labor allocation to biogas, farm and non-farm activities. The Breusch-
231 Pagan test was employed to test the null hypothesis that the error terms of the equations in the
232 system are independent. The results of the test showed that $\chi^2(3) = 10.190$; Pr = 0.017, and
233 therefore the null hypothesis of independence of errors across equations is rejected and hence, the
234 use of Seemingly Unrelated Regression model to estimate the equation is justified.

235 **Table 3: Summary statistics for returns to farm, non-farm and biogas activities**

Variable definition	Log of average returns (UGX)	Standard deviation
Farm activities labor returns	3.2	1.1
Non-farm activities labor returns	2.2	1.5
Biogas activities labor returns	2.0	1.3

236 The returns from labor were converted to logs to ensure normal distribution of activity labor
237 returns. This gave an insight into the returns from each activity and how much a household is likely
238 to forego if it chooses to devote part of its time to biogas activities. Farming had the highest average
239 return, about 64% higher than biogas and 46% higher than non-farm activities.

240 **Table 4: Factors influencing household labor allocation to biogas, farm and non-farm**
241 **activities**

	Farm labor share	Z-statistics	Non-farm labor share	Z-statistics	Biogas labor share	Z-statistics
Constant	-2.35859		-2.91165		0.697311	
Farm activity labor returns	2.951***	6.74	-0.166	-0.54	-0.056	-0.61
Off farm activity labor returns	0.112	0.38	1.324***	6.42	0.053	0.84
Biogas activity labor returns	-0.745**	-2.06	0.121	0.48	0.465***	6.09
Age of household head	0.006	0.19	0.065***	2.75	-0.011	-1.53
Sex of household head (male)	-1.407	-1.6	0.741	1.21	-0.626***	-3.37
Education of household head	0.092	0.83	0.107	1.39	0.001	0.05
Household size	0.034	0.24	-0.248**	-2.5	0.004	0.13
Size of land holding	-0.031	-0.28	-0.239***	-3.11	0.014	0.59
Number of cattle	0.294**	2.48	0.088	1.06	0.123***	4.91
Distance to water source	-0.001	-1.11	1.47E-05	0.03	-0.001***	-2.98
Breusch-Pagan test (χ^2)	10.190**					

242 ***, **, * Significance at 1%, 5% and 10% respectively

243 3.3.1 Activity labor return, cross-labor return and labor share

244 Activity labor returns show positive relationships with the labor share for the activity, indicating
245 that households obtaining higher returns from an activity allocate a larger share of labor to it.
246 However, cross-labor returns between the different activities were negatively related because an
247 increase in returns of one activity reduced labor allocation to other activities. For example, if
248 returns from biogas increase, then households were more likely to increase labor allocation to
249 biogas activities. Therefore, households respond positively to increase in activity returns. This is
250 consistent with findings by Sikei *et al.* (2009) on returns from agriculture, non-farm and forest
251 products.

252 **3.3.2 Age**

253 Age had a positive and significant (1% level of significance) impact on non-farm labor share. This
254 is because older members tend to diversify their income to accumulate as much wealth as possible.
255 As a result, they allocate more labor to non-farm activities. Age is negative and insignificant in
256 biogas labor share. Older household heads were less likely to allocate their labor to biogas; this is
257 because older members may not have the energy to carry out extra activities associated with biogas,
258 such as collecting water, mixing dung, and cleaning the digester. This is consistent with findings
259 from (Parawira, 2009) who stated that some older members without young care takers may not be
260 in a position to take care of animals which are the major source of feed stock for the digester.

261 **3.3.3 Size of land holding**

262 Size of land holding had a negative and significant impact on non-farm activity labor share (1%
263 level of significance). The larger the land size, the less households allocate labor non-farm. This
264 is consistent with findings from Bagamba *et al.* (2007) who stated that farm size is negatively
265 related to amount of time allocated to non-farm activities. Matshe and Young, (2004) noted that
266 farmers undertake non-farm activities because of constraints in getting access to farming land.
267 Larger land holdings require more labor than small ones. Therefore households tended to spend
268 more time working on their own land than diverting labor to other activities. However, size of land
269 holding had no effect on labor supplied to farm and biogas. This is because land is not a major
270 resource in biogas production. This is comparable to findings from Bagamba *et al.* (2009) who

271 concluded that farm size had no effect on labor supply. Hari and Ainun (2013) also found that size
272 of land holding had no effect on labor allocation to farm activities.

273 ***3.3.4 Sex of household head***

274 Sex of the household head had a negative and significant (1% level of significance) impact on
275 biogas labor share. This result implies that being a male decreases labor allocation to biogas
276 activities. Biogas in rural households is mainly used for cooking (Kileo and Akyoo, 2014); as a
277 result, men do not see it as a priority in the household because they do not work in the kitchen as
278 much as women. Results show that 95% of the cooking was done by women and children and
279 only 5% is done by men. Kileo and Akyoo, (2014) further note that a biogas system provides a
280 direct benefit to the women and female children by reducing the drudgery and danger to personal
281 safety related with collecting fuel wood; as a result, female headed households will allocate more
282 labor to biogas production than their male counterparts. Women in male headed households have
283 less control over resources and thus cannot make strong decisions in the households, such as where
284 to allocate household labor. Therefore, female headed households tended to allocate more labor to
285 biogas activities than male headed households. However, sex of the household head was not
286 significant in farm and non-farm activities. This is also consistent with findings from Bagamba *et*
287 *al.*, (2007), who stated that gender had no significant effect on time allocated to farm production
288 and being male increases the chance of working on non-farm activities but decreases the time in
289 home production activities.

290 ***3.3.5 Household size***

291 The number of household members available for labor had a negative and significant (5% level of
292 significance) impact on non-farm labor share but a non-significant impact on farm and biogas labor
293 shares. This implies that households with more members will allocate less labor to non-farm
294 activities. However, Matshe and Young (2004) noted that household size had a positive effect on
295 non-farm labor allocation while Sikei, (2009) found no significant relationship between household
296 size and non-farm labor share.

297 ***3.3.6 Number of cattle owned***

298 The number of cattle owned by the household had a positive and significant impact on farm (5%
299 level of significance) and biogas (1% level of significance) labor share equations. Households with
300 more cattle tend to have more farm related activities compared to their counterparts with less cattle.
301 Therefore, more labor is allocated to the farm. By contrast, Utami and Seruni (2013) noted that
302 increasing number of cattle had little impact on additional household labor requirements on a per
303 farm basis; as herd size increases by 50% about 14% additional household labor would be
304 required. It is also clear that households with more cattle tend to have more feed stock and thus
305 can produce biogas more frequently (Walekhwa *et al.*, 2009). Labor is required for the daily
306 maintenance of the digester (daily mixing and feeding of the digester), therefore households with
307 more cattle are more likely to allocate labor to biogas activities.

308 **3.3.7 Distance to water source**

309 Distance to water source had a negative and significant (1% level of significance) impact on the
310 biogas labor share equation. Water is a key factor in biogas production, so its availability is of
311 paramount importance (Mwirigi *et al.*, 2014). Rutamu, (1999) reported that a typical cow drinks
312 60 liters of water per day and a further 60 liters of water are required for mixing feed stock. The
313 larger the distance to water source, the less the households will engage in biogas activities as water
314 collection will consume much of their precious time. Abadi and Gabrehiwot, (2014) also found a
315 negative relationship between distance to water source and use of biogas technology in Ethiopia.
316 Therefore, households that are very far from water sources allocate less labor to biogas activities.
317 A study by Pandey *et al.* (2007) suggested that biogas is feasible in households with less than 1
318 km distance to water sources.

319 **4. Conclusions**

320 Factors influencing labor allocation to farm, biogas and non-farm activities included activity labor
321 returns, age of the household head, sex of the household head, number of household members
322 available for labor (size of family labor), size of land holding, number of cattle owned by the
323 household and distance to the nearest water source. Increases in own activity labor returns
324 increases allocation of labor to that activity. Female headed households allocate some of their labor
325 to biogas activities. Households with more cattle allocate their labor to farm and biogas activities

326 due to ease of access to feedstock. Households with easy access to water also allocate some of
327 their labor to biogas production, since they spend less time searching for water. This means that
328 households close to water sources and/or those that practice water harvesting are in a better
329 position to allocate some labor to biogas and use the other portion of their labor for other livelihood
330 activities without constraining any of the household day to day activities. Age of the household
331 head had no significant influence on labor allocation to biogas activities though it positively
332 influenced labor allocation to non-farm activities. Size of land holding also had no significant
333 effect on labor allocation to farm and biogas activities though it negatively influenced labor
334 allocation to non-farm activities.

335 Based on the study findings, we recommend that in choosing the households where biogas
336 digesters should be installed, biogas promoters should carefully assess the level of resource
337 endowment by these households through baseline studies. Special attention should be given to
338 quantifying available resources, such as size of household labor, quantity of feedstock and
339 availability of water since these are the major resource requirements for biogas production.

340 **Acknowledgments:**

341 This work was supported by funding from the African Union Commission to the Afri-flame
342 network under the project: Adaptation of small-scale biogas digesters for use in rural households
343 in Sub-Saharan Africa, grant number AURG/2/058/2012.

344 **Conflict of interest:** The authors have no conflict of interest

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