Journal of Nature Studies 15 (2): 23-36
ISSN: 1655-3179

OPTIMIZATION OF THE LOCATIONS OF CASSAVA POSTHARVEST FACILITIES IN SURALLAH, SOUTH COTABATO, PHILIPPINES

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ABSTRACT – The municipality of Surallah has the highest production capacity of cassava in South Cotabato. In this study, the optimal locations of cassava postharvest facilities to be built in Surallah were determined using the formulated *p-center* facility location model which optimized the total transportation cost. Results showed that barangays Centrala, Lamsugod and Naci were the best locations should there be three additional postharvest facilities. The developed model was able to reliably identify which barangays in Surallah should be catered by each of the located postharvest facility. Through the use of these additional postharvest facilities, a kilogram of cassava tubers processed in a postharvest facility generates a profit of 2.74 Php. This is higher by 0.48 Php as compared to the current average profit per kilogram of processed cassava. Moreover, a hectare of land planted with cassava produces an estimated profit of about 93,060 Php, which is higher by 16,427 Php based on the current average profit per hectare of 76,633 Php.

Key words: postharvest facility, p-center, facility location, binary integer model, cassava, optimization

INTRODUCTION

Cassava (*Manihot esculenta)* is a perennial woody shrub that originally came from Brazil that is now widely grown in some of the areas of Africa and Asia . Cassava was formerly considered as a poor man's crop by the Food and Agriculture Organization (FAO) but lately, it has been gaining economic interest because of its significant diverse utilization – food, animal feed, alcohol, textile, medicine and biodegradable products. It is highly tolerant to drought and acid soils, and can actually grow well even with a small amount of water (Plucknett, et al., 2000). Cassava, in general, has the ability not only to secure food needs, but also to serve as source of higher incomes for producers and traders and engine for rural industrial development. Because of its flexible characteristics for survival, the global production of this crop is about 250 million metric tons (MT) per year, in which 50% was contributed by Africa. The Philippines is a large producer and consumer of cassava, but its production is small compared to the production of other Asian countries like Thailand and Indonesia (Calica, et al., 2015).

To cite this paper: De Lara, M. L. D., Rolluque, E. J. P & Serrano, D. L. F. 2016. Optimization of the Locations of Cassava Postharvest Facilities in Surallah, South Cotabato, Philippines. *Journal of Nature Studies*. 15 (2): 23-36

Cassava farmers have the option to sell cassava fresh tubers or sell processed, dried and granulated, cassava to the assemblers. The later will give the farmers higher profit and it will also generate job opportunities for peelers, chippers, machine operators and haulers. Despite being a top cassava producing municipality in the Philippines, Suralah has only one assembler. Because of this, the current common practice of the cassava farmers in Surallah is to plant cassava and contact the assembler, who has postharvest processing facilities, when the crops are ready for harvesting. The assembler will then process the cassava tubers into dried cassava granules and sell these to feed millers. Incomes of farmers are, thus, mostly limited to the amount of cassava that they can produce since they have no, if not limited, access to postharvest facilities. Thus, it is essential to put up postharvest facilities that are accessible to farmers. It should also be noted that accessible postharvest facilities will result to lower transportation costs, higher income for farmers and less spoilage and losses due to the perishability nature of cassava (PRDP, Region XII, 2014).

Putting up a number of postharvest facilities in the region can clearly increase the profit of farmers from planting cassava (Calica, et al., 2015). But the number of postharvest facilities that should be built and the location where these PFHs be built are very essential. This whole problem of optimizing the locations of postharvest facilities in Surallah, South Cotabato is a capacitated facility location problem. In a *capacitated* facility location problem, the goal is to determine the location of a number of facilities and the demand points that it will serve, so that the sum of distances between any demand location and the facility serving it is minimized, and all the demand are catered by the facilities. This is equivalent to minimizing the average distances or cost from the demand points and the facilities.

With that, this study focused on answering the following objectives: to formulate the problem of optimizing the postharvest facility location in Suralah, South Cotabato as a mathematical model, to identify the minimum number of cassava postharvest facilities that should be built, to determine the respective locations of the postharvest facilities that should be built such that the average transportation costs from barangays to the assembler via the postharvest facilities are minimized, to determine which barangays in Surallah, South Cotabato should be catered by each cassava postharvest facility and to determine the probable increase in the farmers' profit if the postharvest facilities is built.

METHODOLOGY

A. Data Gathering

The Agricultural Mechanization Development Program (AMDP) of the University of the Philippines, Los Baños through its project entitled "Comprehensive Assessment of the Performance of Cassava Supply Chain and Value Chain and Identification of Intervention for Competitiveness" provided the following information: names of barangays in Surallah, South Cotabato and its locations, barangay where the sole assembler is located, amount of cassava tubers each barangay can produce or production capacity, recovery rates of cassava tubers, cost producing cassava tubers per unit, selling price of cassava tubers per unit, selling price of granulated cassava per unit, cost of transporting granulated cassava per unit per unit of distance, cost of transporting cassava tubers per unit per unit of distance, cost of processing cassava tubers in a postharvest facility per unit, and minimum and maximum capacity of a postharvest facility.

The amount of cassava tubers each barangay can produce were obtained from the Municipal Agriculture Office of Surallah, South Cotabato. Table 1 gives the production capacities of each barangay as of 2014 using the average yield of 34,000 kg per hectare of land planted to cassava. Also, each barangay was given its assigned number i.e. barangay 1 will be Buenavista, barangay 2 wil be Canahay and so on.

Table 1. Amount of cassava (in kg) produced by each barangay in Surallah as of 2014.

i	Barangay	Production Capacity in kg/year
1	Buenavista	51,000
2	Canahay	289,000
3	Centrala	4,080,000
4	Colongolo	2,244,000
5	Dajay	340,000
6	Duengas	986,000
7	Lambontong	2,754,000
8	Lamian	1,700,000
9	Lamsugod	6,494,000
10	Libertad	68,000
11	L.Baguio	34,000
12	Moloy	68,000
13	Naci	5,338,000
14	Talahik	129,200
15	Tubi-ala	2,142,000
16	Upper Sepaka	119,000
17	Veterans	238,000
	TOTAL (Surallah)	27,074,200

Table 2 shows the logistics costs, selling prices and costs of processes. The data were gathered through key informant interviews and focus group discussions with the officials of the Department of Agriculture and Surallah Municipal Agriculture Office and farmers of Surallah, South Cotabato last September 2014. Mr. Alvin Chris Daraug of the sole assembler in Surallah, South Cotabato is one of the key informants who provided the many of the relevant information.

Table 2. Logistics costs, selling prices and cassava processing costs in Surallah.

Description	Cost	Remarks
cost of producing cassava tubers	PHP 0.45 /kg	
selling price of casssava tubers	PHP 3.1 /kg	PHP 3.1 /kg if delivered to the assembler PHP 2.8 /kg if harvested by the assembler
selling price of unpeeled granulated cassava	PHP 10.5 /kg	
cost of transporting cassava tubers	PHP 0.008 /kg/km	Cost of trucking= PHP 0.2 per 20km (average distance from farmer to trader)
cost of transporting granulated cassava	PHP 0.00470035 /kg/km	Cost of trucking from Surallah to SMC General Santos = PHP 0.4 (85.1 km)
cost of chipping (mechanical) cassava tubers	PHP 0.2 /kg	
cost drying, granulation, and loading of granulated cassava	PHP 0.19 /kg	Drying (3-5 days depending on the weather) + Granulation + Loading to truck: P14/sack (75kg/sack)
cost of sacking cassava tubers or granules	PHP 0.13 /kg	
cost harvesting and loading and unloading tubers	PHP 0.2 /kg	
maximum capacity of a postharvest facility (PHF)	13,440,000 kg	Based on the volume of cassava granules delivered by the assembler to SMC per year.
minimum capacity of a PHF	6,720,000.00 kg	50% of the maximum capacity of a PHF

The respective locations of the barangays in Surallah using Wikimapia, an online “multi-lingual, open-content, collaborative map” were identified. After getting each barangays’ location in Wikimapia, the road distances between each barangays were obtained in Google Maps, another online map which “provides directions, interactive *maps*, and satellite/aerial imagery of many countries”. However, the location provided by Wikimapia is in degrees, minutes and seconds (DMS) while the locations accepted by Google Maps should be in Latitude and Longitude (LatLong) formats. Thus, Satellite Signals, an online converter of DMS to LatLong, was used to convert DMS to LatLong.

Figure 1: Map of the Municipality of Surallah, South Cotabato, Source: Google Map

B. Model Development

The following assumptions were identified for the development of the model, with due consideration to the current situation of the cassava industry in Surallah, South Cotabato:

1. Every barangay is a candidate site for a postharvest facility (PHF).
2. Farmers from the barangays only transport, at their own expense, fresh cassava tubers to the PHFs.
3. The PHFs are "ideal postharvest facilities" that is, all the processes in the PHFs are mechanical.
4. Each barangay is assigned to use only one PHF.
5. All PHFs have the same capacity.
6. All the PHFs cater to only one assembler.
7. From the PHFs, the granulated cassavas are all brought to the sole assembler where the transportation cost is shouldered by the farmer.
8. The minimum road distances are considered in identifying the distances between two barangays.

The model used for this particular postharvest facility location problem was based on the standard *p-center* problem of locating *p* facilities which minimizes the distance between the demand node and the facility assigned to it. However, in this model, the costs of transportation are minimized instead of distances. The binary integer model is given below.

$$Minimize\ W = \sum_{i=1}^{m}\sum_{j=1}^{n} q_{i,j}y_{i,j} \qquad (1)$$

W is the sum of the costs of transporting cassava tubers from barangay i to the assembler in Brgy. Tubi'alla after undergoing postharvest processes in barangay j.

Barangay i will use only one PHF.

$$\sum_{j=1}^{n} y_{i,j} = 1, \forall i \qquad (2)$$

Assignment of barangay is restricted to an open PHF.

$$y_{i,j} - x_j \leq 0, \forall i, \forall j \qquad (3)$$

Cassava tubers transported to PHF j will not exceed its maximum capacity.

$$\sum_{i=1}^{m} a_i y_{i,j} - UBx_j \leq 0, \forall j \qquad (4)$$

Cassava tubers transported to PHF j will not be lower than its minimum capacity.

$$LBx_j - \sum_{i=1}^{m} a_i y_{i,j} \leq 0, \forall j \qquad (5)$$

Locate exactly *P* PHFs.

$$\sum_{j=1}^{n} x_j = P \qquad (6)$$

Standard integer constraints.

$$x_j \in \{0,1\}, \forall j$$
$$y_{i,j} \in \{0,1\}, \forall i, \forall j \qquad (7)$$

$i = 1, 2, \ldots, 17$ (*where each i represents a barangay in Surallah*)
$j = 1, 2, \ldots, 17$ (*where each j represents a barangay in Surallah as a candidate site*)
a_i = *amount of cassava tubers barangay i can produce*
$r_{i,j}$ = *total cost of transporting cassava tubers from barangay i to barangay j*
$s_{i,j,15}$ = *total cost of transporting granulated cassava*
(*which came from barangay i as tubers*) *to barangay* 15 (*assembler*)
$q_{i,j} = r_{i,j} + s_{i,j,15}$
(*total cost of transportation from barangay i to assembler via PHF j*)
LB = *minimum capacity of a PHF*
UB = *maximum capacity of a PHF*

The decision variables are

$$x_j = \begin{cases} 1, & \text{locate PHF at candidate site } j \\ 0, & \text{do not locate at candidate site } j \end{cases}$$
$$y_{i,j} = \begin{cases} 1, & \text{if area } i \text{ will use PHF } j \\ 0, & \text{if are } i \text{ will not use PHF } j \end{cases}$$

C. Computation of the Transportation Costs

Let the following be:
a_i = amount (in kg) of cassava tubers barangay i can produce
$d_{i,j}$ = distance between barangay i and barangay j in km
$d_{j,15}$ = distance between barangay j (candidate site) and barangay Tubi'alla (assembler) in km
Cost of transporting cassava tubers per kg per km = 0.008 kg/km
Cost of transporting granulated cassava per kg per km= 0.004700352 kg/km
$r_{i,j}$ = total cost of transporting cassava tubers from barangay i to barangay j
$s_{i,j,15}$= total cost of transporting granulated cassava (which came from barangay i as tubers) to the assembler
$q_{i,j} = r_{i,j} + s_{i,j,15}$ (Total cost of transportation from barangay i to the assembler via PHF in barangay j)

For the transportation costs, $r_{i,j}$, $s_{j,15}$ and $q_{i,j}$ were computed as follows

$$r_{i,j} = (0.008\ \ kg/km) a_i\, d_{i,j}$$
$$s_{i,j,15} = (0.004700352\ kg/km)(0.38\, a_i)\, d_{j,15}$$
$$q_{i,j} = r_{i,j} + s_{i,j,15}.$$

For $s_{i,j,15}$, only 38% of the total production cost of barangay i was considered since the recovery rate of cassava tubers after granulation is 38%. Also, the expression $q_{i,j}$ now represents the total cost of transporting the cassava tubers from barangay i to the assembler in barangay Tubi'alla after undergoing postharvest processes in its assigned postharvest facility in barangay j.

D. Computation of the Profit

To compute the profit of a barangay if it will utilize the postharvest assigned to it by the model, the following were needed for the computations:

Let the following be:
a_i = amount (in kg) of cassava tubers barangay i can produce
$d_{i,j}$ = distance between barangay i and barangay j in km
$d_{j,15}$ = distance between barangay j (candidate site) and barangay Tubi'alla (assembler) in km
Cost of transporting cassava tubers per kg per km = 0.008 kg/km
Cost of transporting granulated cassava per kg per km= 0.004700352 kg/km
$r_{i,j}$ = total cost of transporting cassava tubers from barangay i to barangay j
$s_{i,j,15}$= total cost of transporting granulated cassava (which came from barangay i as tubers) to the assembler
$q_{i,j} = r_{i,j} + s_{i,j,15}$ (Total cost of transportation from barangay i to the assembler via PHF in barangay j)

For the transportation costs, $r_{i,j}$, $s_{j,15}$ and $q_{i,j}$ were computed as follows
$r_{i,j} = (0.008\ kg/km)a_i\ d_{i,j}$
$s_{i,j,15} = (0.004700352\ kg/km)(0.38\ a_i)\ d_{j,15}$
$q_{i,j} = r_{i,j} + s_{i,j,15}$.

The profit of each barangay under two scenarios were computed, that without using a postharvest facility and that with using one. Then, the two profits were compared so as to get the increase in profit if each barangay will use a postharvest facility.

Table 3 shows how the total annual expenses, income and profit of a barangay with and without using a postharvest facility were computed. It also shows how to get the annual profit per hectare of land planted to cassava and per kilogram of cassava produced by a barangay. To compute the increase in expenses, income and profit when using a postharvest facility, the difference of the both the income, expenses and profit of using a postharvest facility and not using were computed

Table 3. Income, expenses and profit formulas.

	Annual Income	Annual Expenses	Annual Profit	Annual Profit per ha planted to cassava tubers	Annual Profit per kg of cassava tubers produced
Using a Postharvest Facility j	10.5 (0.38 a_i)	$a_i(b + hlu + cs + cc + dgl) + (0.38a_i cs) + r_{i,j} + s_{i,j,15}$	Annual Income – Annual Expenses	$\frac{Annual\ Profit}{ha_i}$	$\frac{Annual\ Profit}{a_i}$
Without Using a Postharvest Facility j	3.1 a_i	$a_i(b + hlu + cs) + r_{i,15}$	Annual Income – Annual Expenses	$\frac{Annual\ Profit}{ha_i}$	$\frac{Annual\ Profit}{a_i}$

RESULTS AND DISCUSSION

The binary integer facility location problem was solved using the software Qsopt, a linear programming solver. The problem was first solved using P = 1, 2, 3, 4 and 5, where P is the number of PHF and capacity constraints were not yet considered. Table 4.a and Table 4.b shows the optimal locations of the supposed PHF depending on the value of P and the corresponding barangays to be served by each PHF. It also shows the corresponding total transportation cost and total annual profit corresponding to Surallah's annual cassava production capacity of 27,074,200 kilograms. Moreover, profit per kilogram of cassava, as shown in the table, increases as the number of PHF increases and as the PHFs become more accessible.

Table 4.a. Results of locating 1, 2 and 3 postharvest facilities without considering capacity constraints.

P	Total Transportation Cost (in pesos)	Total Annual Profit (in PHP)	Total Profit per kg (in PHP)	Location of PHFs	Assigned Barangays
1	1,739,722.29	73,272,056.63	**2.71**	Buenavista	All Barangays
2	1,172,901.97	73,838,875.97	**2.73**	Colongulo	Colongulo Dajay Duengas Canahay Little Baguio Moloy Talahik Upper Sepaka
				Tubi'alla	Buenavista Centrala Lambontong Lamian Lamsugod Libertad Naci Tubi'alla Veterans
3	907,875.63	74,103,903.37	**2.74**	Colongulo	Colongulo Dajay Duengas Canahay Little Baguio Moloy Upper Sepaka
				Lamsugod	Lambontong Lamian Lamsugod Veterans
				Naci	Buenavista Centrala Libertad Naci Talahik Tubi'alla

Table 4.b. Results of locating 4 and 5 postharvest facilities without considering capacity constraints.

P	Transportation Cost (in pesos)	Total Annual Profit (in PHP)	Total Profit per kg (in PHP)	Location of PHFs	Assigned Barangays
4	767,039.43	74,244,739.40	**2.74**	Colongulo	Colongulo Canahay Little Baguio Moloy
				Lamsugod	Lambontong Lamian Lamsugod Veterans
				Naci	Buenavista Centrala Libertad Naci Tubi'alla
				Dajay	Dajay Duengas Talahik Upper Sepaka
5	670,302.03	74,341,476.76	**2.75**	Colongulo	Colongulo Canahay Little Baguio Moloy
				Lamsugod	Lamsugod Veterans
				Naci	Buenavista Centrala Libertad Naci Tubi'alla
				Dajay	Dajay Duengas Talahik Upper Sepaka
				Lambontong	Lambontong Lamian

The postharvest facility location problem was solved at different values of P since the optimal number of P depends on the capacity of each postharvest facility. Moreover, if each postharvest will be similar to the existing postharvest facility in the sole assembler in Surallah, which is 13,440,000 kilogram per year, then there should be three postharvest facilities to turn all cassava tubers into dried cassava granules. However, this may vary depending on the design of the postharvest facility. That is why, the problem was solved at different values of P. Moreover, it can be noticed that, if 3 facilities were to be located, barangays Colongulo, Lamsugod and Naci are the optimal locations. Significantly, Brgy. Lamsugod is notably the barangay with the highest production capacity while Brgy. Naci comes second.

From this point on, adding more facilities will not make the 3 barangays less optimal. As P increases barangays Colongulo, Lamsugod and Naci were consistently part of the optimal solutions.

Through the use of three additional postharvest facilities, a kilogram of cassava tubers processed in a postharvest facility will give a profit of 2.74 Php. This is higher by 0.48 Php when compared to the current average profit per kilogram of processed cassava, which is 2.28 Php. Moreover, a hectare of land planted with cassava will give an estimated profit of about 93,060 Php, which is higher by 16,427 Php against the current average profit per hectare which is pegged at 76,633 Php. Figure 2, an edited version of Figure 1, shows the optimal locations of the 3 postharvest facilities and corresponding barangays that should be catered by each postharvest facility.

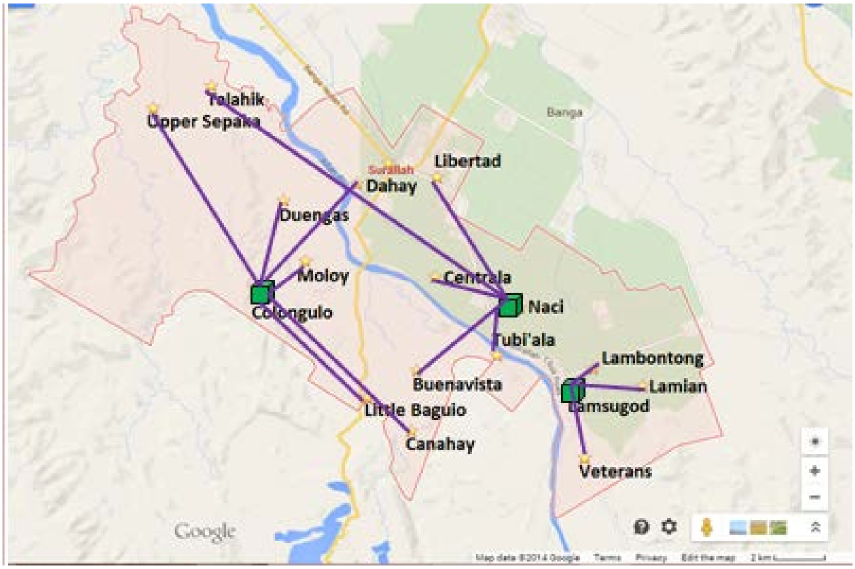

Figure 2. Illustration of the optimal facility location when P is 3.

Now, supposed that each postharvest facility should operate only when each one can surpass the minimum capacity of 6,720,000 kilograms per year. This lower limit is 50% of the maximum capacity of the current postharvest facility of the sole assembler in Surallah. And, assuming that 3 postharvest facilities should be put up, then, the solution is to locate postharvest facility in barangays Colongulo, Lamsugod, and Naci. This strategy is the same solution given by the model where P is 3, but without considering the capacity constraint. This solution will also give a total annual profit of PHP 74,103,903.37 and a total transportation cost of PHP 907,875.63. Table 5 shows the optimal location of the 3 postharvest facilities and the corresponding barangays that it should be catered when the postharvest facilities have a minimum operating capacity of 50%.

Table 5. Results of locating 3 postharvest facilities considering the capacity constraints.

Locations of Postharvest Facilies	Brgy. Colongulo	Brgy. Lamsugod	Brgy. Naci
Assigned Barangays	1. Colongulo	1. Lambontong	1. Buenavista
	2. Dajay	2. Lamian	2. Centrala
	3. Duengas	3. Lamsugod	3. Libertad
	4. Canahay	4. Veterans	4. Naci
	5. Little Baguio		5. Talahik
	6. Moloy		6. Tubi'alla
	7. Upper Sepaka		

SUMMARY AND CONCLUSION

Cassava has been recently gaining economic drive because of its ability to have good yield where other crops cannot survive. Also, aside from the variety of uses that cassava has, there are a number of multiple benefits and advantages from this crop. With cassava farmers having limited or no access to postharvest facilities, putting up postharvest facilities is of great help among farmers from Surallah, South Cotabato.

This paper presents a methodology to find the optimal locations of the possible postharvest facilities to be located in the municipality of Surallah in South Cotabato. The binary integer programming problem at different values of P and with the nonexistence and existence of capacity constraint was formulated and solved. With the use of the software Qsopt, the optimal locations of the postharvest facility to be used by the cassava farmers in Surallah, South Cotabato were determined.

One of the most important observations is that as the number of postharvest facilities to be located increases, the transportation cost decreases and the farmers' profit increases. However, building numerous postharvest facilities means spending more money for the machines and the construction of the facilities. Moreover, locating more than 3 postharvest facilities will be beneficial also since 5,688 hectares of land in South Cotabato, were identified as possible expansion sites for planting cassava and 1500 hectares of these lands are in Surallah. Also, the excess processing capacity of these postharvest facilities can be utilized by other farmers from nearby municipalities since according to PRDP of Region XII, the other municipalities of South Cotabato goes from having limited postharvest facilities to none at all.

Furthermore, since the postharvest facilities are yet to be built, the number of postharvest facilities may vary depending on the available budget. Also, after locating the optimal sites for the facilities, the decision maker, the Municipal Agricultural Office of Surallah in coordination with the private sector, must then allocate postharvest machines in a postharvest facility with enough capacities to cater the production capacities of the barangays assigned to it. Also, they can adjust the size of the facility depending on the machineries to be placed there.

RECOMMENDATIONS

This study aimed to reduce the total transportation cost of transforming cassava fresh tubers into granules. This in effect will hopefully increase the profit of cassava farmers. However, some points and modifications can be applied in the study for improvement or for further studies. These include considering the actual distances, as compared to only road distances since most cassava farms are actually on the mountains or high terrains. The transportation costs used in this study is directly proportional to the distance i.e. the farther the distance, the higher the transportation cost is. But, other logistics factors could be considered such as cost of fuel, trucking costs, driver's allowance, hauling costs and warehouse costs. It is also better if there is a separate study that will determine the actual operating capacity of desired postharvest facilities and a cost analysis of putting up a postharvest facility.

ACKNOWLEDGEMENT

This study has been possible with the support from UPLB's Agricultural Mechanization Development Program and the Department of Agriculture Bureau of Agrarian Reform through the Comprehensive Assessment of the Performance of the Cassava Value Chain and Identification of Interventions for Competitiveness project.

STATEMENT OF AUTHORSHIP

The first author, who is the study leader, established the direction of the study and the methodology employed. He is also the lead writer of the paper. The second and the third author implemented the encoding, programming and computations and helped in the writing process.

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JOURNAL OF NATURE STUDIES
(formerly Nature's Bulletin)
ISSN: 1655-3179