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Projection of cassava production due to introduced cassava processing technologies: Goal Programming Approach

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ABSTRACT: This study was proposed to project future production of cassava due to introduced cassava processing technologies in Mikongeni (Kibaha district) and Tongwe village (Muheza district) in Tanzania. Primary data were generated from 120 consumers who were randomly selected with the use of questionnaire, focus group discussion and experimentation. The study projected the future trend of production for cassava using goal programming approach and indicated that about 128 571.4 tonnes (an increase of 60.7% per year) can be produced per annum in the two districts, if farmers use the said technology in full scale. The study recommended that the farmers have to be informed on the growing demand of the mechanically processed cassava products, thus the need to meet this demand.

KEYWORDS: cassava, goal programming, processing technologies, demand, projection.

1 INTRODUCTION

BACKGROUND INFORMATION

Cassava (*Manihotesculenta* Crantz) is the starchy root crop that is grown almost entirely within the tropics. Although it is one of the most important crops in the tropical countries, it is little known elsewhere in some parts within the tropics, and considered to be a low grade substance crop (Cock, 2001).

Cassava ranks second in the list of staple food crops in developing countries after maize (Nweke, 2003). In sub-Saharan Africa, cassava is grown chiefly as human food, but it is also an important animal feed and has several industrial uses. Being one of cheapest source of food energy, cassava gives a carbohydrate production per hectare which is about 40% higher than rice and 25% more than maize. Thus cassava plays a major role in meeting developing countries' rising demand for consumption of both food and animal feed (Tonukari, 2004).

The total area harvested in the world in 2005 was about 16 million hectares, with 57% in Africa, 25% in Asia and 18% in Latin America. About 15% of the world's population of cassava is exported to Europe and Japan as chips, pellets and/or starch. The starch is used in food industries, textiles, paper industries and in beer brewing. The remaining 85% of the world production is used within the producing countries for food (58%), animal feed (28%) and industrial uses (3%) where the wastage is about 11% (CIAT, 1993).

The area of land planted with cassava is greatest in Africa, but yields are lower than other continents, where in 2005 Africa, Asia and Latin America had 12 354 000, 3 429 000 and 2 649 000 hectares of land planted with cassava whereas productions were 109 755, 56 082 and 34 094 (000 metric tonnes) respectively (Prakash, 2008).

In Tanzania, cassava is grown in most parts of the country. However, chief growing areas are Tanga, Mwanza, Pwani and Lindi regions. In recent years, cassava is also grown in other parts of the country as a result of Government efforts to stimulate local self-sufficiency in food supply (Nang'ayo *et al*., 2007); as such, making cassava the most important root crop in the country. Despite its importance, Tanzania is estimated to produce 6.3 million tons of cassava per year.

The main inherent problems with cassava include high perishability of the edible roots within 2-3 days after harvesting, high level cyanogenic glucosides in some variation (Mlingi and Ndunguru, 2003) and low nutritional value as it is mainly composed of starch. In addition, there exists stigma in some transects of Tanzanians to regard cassava as a poor man's food, therefore reduced production and consumption of cassava and increased vulnerability of cassava farmers to poverty.

One solution to the perishability problem has been to leave the crop in the field and harvest in piecemeal only where there is need but this is uneconomical because it ties up the land unnecessarily. Another solution is to transfer the risk by selling the crop to businessman while still in the field at price set arbitrary and often very low, which gives very little income to farmers and thus a disincentive to increased cassava production. A noble solution has been to process the roots into shelf-stable product, for example flour but the methods used are still inadequate as in most area they are tedious, rudimentary and unhygienic, often leading to insufficient processing and poor quality products (Silayo *at al*., 2004).

Both the tuber and leaves of cassava contain Cyanogenic glucosides, which may lead to toxicity if cassava is not properly processed. Safe consumption of cassava depends on successful removal of cyanogens. The percentage of cyanide reduction varies from 70 to 100% depending n the kind of processing method used (Nwapa, 1986). In order to minimize the cyanogens content, cassava is processed by different traditional methods, which includes fermentation (wet and solid-state) and drying. However, in solid state fermentation and drying, there is proliferation of spoilage and pathogenic micro-organisms on cassava, some of which may produce mycotoxins (Nwapa, 1986). The resulting flour is coloured thus not appealing to the consumer.

A recent study on consumer preference on mechanical processed cassava products has revealed that there is an increasing demand for the products (Theodory, 2010). The increase in demand pulls the production and hence the future production of cassava had to be known beforehand. Studies conducted on cassava in Tanzania (Silayo *et al.,* 2004; Laswai *et al.,* 2005) have focused more on processing and processed products of cassava, but the studies did not revealed the future production of the cassava. Therefore, this paper was proposed to evaluate the future cassava production due to the introduced cassava processing technologies using goal programming approach.

2 THEORETICAL APPROACH

DEMAND FOR CASSAVA

Due to higher population growth rates and higher levels of cassava consumption the greatest growth potential for the use of cassava as a human food appears to exist in Africa. Equally, Asia has shown some signs of growth, while Latin America a slight decline. In Tanzania, the situational analysis showed that there is a big potential demand for cassava. The current supply of fresh unpeeled cassava for immediate domestic consumption is far below demand, with unsatisfied market. Peeled and dried cassava chips as raw materials for human food and processing industries are in short supply. The same is experienced for unpeeled dried chips as raw materials for livestock feeds industries. Moreover, a long term potential is the market for fresh unpeeled cassava roots for starch processing industries (if well invested in) (TAC, 2004).

Demographic changes provide both a challenge and an opportunity for increased demand for cassava as a human food. On the other hand, the increasing urban population provides an opportunity to sell more cassava if the product is of good quality and competitive price. Domestically therefore, growing urbanization offers opportunities to develop new, or unexploited markets for cassava (Ponte, 2001). Increased demand for cassava and its products caused the emergence of different cassava processing technologies in different cassava growing areas in the world.

PROJECTION FUTURE PRODUCTION OF CASSAVA INDUCED BY INTRODUCING MECHANIZED CASSAVA PROCESSING TECHNOLOGIES

Itharattana (2003) attempted to forecast cassava production in Thailand at two levels, national and regional levels. Ordinary Least Square (OLS) was used to estimate the coefficients in each equation. Cobb-Douglas type was applied in the planted area equation while time series model was used in the yield one. Applying the model for the *ex-ante* forecast, the total production was expected to be almost the same in 2002 when compared with the previous year. Weaknesses in the model still remain in terms of some specification errors. Thus, to make *ex-ante* forecast more useful, some policy variables should be added to reflect the real situation. The situation above shows that there is need to employ goal programming approach for solving the multi-objective function.

The approach has been used in river flow forecasting which constitutes one of the most important applications in hydrology. Several methods have been developed for this purpose and one of the most famous techniques is the auto regressive moving average (ARMA) model. The goal was used to minimize the error for a specific season of the year as well as for the complete series of years. Goal programming (GP) was used to estimate the ARMA model parameters. Shaloo Bridge station on the Karun River with 68 years of observed stream flow data was selected to evaluate the performance of the proposed (GP) approach. The results when compared with the usual method of maximum likelihood estimation were favourable with respect to the new proposed algorithm (GP approach) (Mohammadi *et al.,* 2006).

Most of fishery related literature have used lexicographic goal programming (LGP) model for the fishery planning problem and the solution under the decision-maker's priority structure is considered as the optimal solution (Sharma *et al*., 2006). However, in different complex decision-making situations, the desired solution may not be acceptable under the imposed priority structure; that is, a better solution is always expected for which a number of priority structures may be considered (Sharma *et al*., 2003).

A major strength of goal programming is its simplicity and ease of use. This account for the large number of goal programming applications in many and diverse fields (Jones and Tamiz, 2002). As weighted or non pre-emptive goal programmes can be solved by widely available linear programming computer packages, finding a solution tool is not difficult in most cases. Lexicographic goal programmes can be solved as a series of linear programming models (Ignizio and Cavalier, 1994).

Goal programming can hence handle relatively large numbers of variables, constraints and objectives. A debated weakness is the ability of goal programming to produce solutions that are not *Pareto* efficient. This violates a fundamental concept of decision theory that, there is no rational decision maker will knowingly choose a solution that is not *Pareto* efficient. However, techniques are available (Tamiz*et al*., 1999) to detect when this occurs and project the solution onto the *Pareto* efficient solution in an appropriate manner. The setting of appropriate weights in the goal programming model is another area that has caused debate, with some authors (Gass, 1987) suggesting the use of the Analytic Hierarchy Process (AHP) or interactive methods (Ciptomulyono, 2008) for this purpose.

3 METHODOLOGY

LOCATION OF THE STUDY AREA

The research was conducted at Tongwe village in Muheza District (Tanga region) and at Mikongeni village in Kibaha district (Pwani region). These have been chosen because cassava is widely cultivated by many farmers and cassava processing technologies (both traditional and mechanical) are used. Moreover, the study areas are in close proximity to urban markets such as Tanga and Dar es Salaam where there is potential growing demand for cassava and its respective products.

RESEARCH DESIGN

A cross sectional research design was used where data were collected at a single point in time. The reason for choosing this design is simply because it is flexible, economical and easy to manipulate data and information (Bailey, 1994).

SAMPLING PROCEDURE AND SAMPLE SIZE

Purposeful sampling was used to select two villages where there is an on-going PANTIL cassava project whereby Mikongeni village (Kibaha district) and Tongwe (Muheza district. Then proportionate stratified sampling based on their income (i.e. those with low income versus those with high income) was employed. Thereafter, random sampling was employed to get a sample of 30 respondents from each stratum. Ultimately sample of 120 respondents were used for this study. A sample size of 30 respondents is deemed large enough. The Central Limit Theorem (CLT) states that the average from a random sample for any population, with finite variance, has an asymptotic standard normal distribution. Most estimators encountered in statistics and econometrics can be written as functions of sample averages. Therefore, the t-statistic was used as inference test of the model, based on the law of large numbers and the Central Limit theorem (CLT).

DATA COLLECTION

Structured questionnaires with both closed and open-ended questions, group discussions and observation were used as methods for collecting primary data. Data were collected through interview of the sampled households and key informants who were the village chairmen and agricultural field officers to each village. The key variables asked were the farmers (household) characteristics, household sources of income, cassava production, processing (traditional, wet and dry and mechanical) and consumption.

The experimentations were used to collect information on efficiency (in terms of operational, time, fuel consumption) of the mechanical processing technology from the study area. The experiments were conducted by taking 5 kg of chunks/pieces of pealed cassava into each machine (manual cassava chipper, engine powered cassava chipper and cassava grater). The time used to process the cassava by each machine was recorded by using stopwatch as a pilot, and then the experiments were repeated four times, whereas deep stick was used to measure the fuel level.

DATA ANALYSIS

Goal programming is a branch of multi-objective optimization, which in turn is a branch of multi-criteria decision analysis (MCDA), also known as multiple-criteria decision making (MCDM). It can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures (Pournamdarin, 2008). Each of these measures is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimized in an achievement function. This can be a vector or a weighted sum dependent on the goal programming variant used as satisfaction of the target which deemed to satisfy the decision makers (Andrew *et al*., 2008). This approach was used to project the future production of cassava resulting in a change of cassava processing technology and consumption behavior by using LP-WYE software; it was formulated as follows;

Objective function:

Max $Z(Q)$

Subject to $C_r(Q) - g_r = u_r^+ - u_r^-$, *r =1 to k*

Non-negativity

$$u_r^+, u_r^- \geq 0, \; r = 1 \text{ to } k \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where;

$Z(Q)$ = The production function for cassava maximization (Objective function)

G_r = The goal or target value

u_r^+ = The positive deviation from the goal or target value set

u_r^- =The negative deviation from the goal or target value set

Q = Is a summation of Q_1 and Q_2 which are bitter and sweet varieties respectively

C_r(Q) = The constraints of the objective function were as follows:

The consumption is given the first priority level i.e.

$$C_o(Q) - G_{CO} = U_{CO}^+ - U_{CO}^- \quad \ldots\ldots\ldots\ldots \quad (2)$$

The variety is given the second priority level i.e.

$$V(Q) - G_V = U_V^+ - U_V^- \quad \ldots\ldots\ldots\ldots \quad (3)$$

The access to market is given the third priority level i.e.

$$M(Q) - G_m = U_m^+ - U_m^- \quad \ldots\ldots\ldots\ldots \quad (4)$$

The cost of processing is given the fourth priority level i.e.

$$C_c(Q) - G_c = U_c^+ - U_c^- \quad \ldots\ldots\ldots\ldots \quad (5)$$

The price of the processed products is given the fifth priority level i.e.

$$P_p(Q) - G_p = U_p^+ - U_p^- \quad \ldots\ldots\ldots\ldots \quad (6)$$

Where:

$C_o(Q)$ = Consumption function, G_{co}= Goal set for consumption, V(Q)= Variety function, G_v= Goal set for variety production, M(Q) = The quantity of Cassava accessed to the market, G_m = Goal set for quantity to be accessible to the market, $C_c(Q)$ = Cost processing function, G_c = Goal set for processing cost, $P_p(Q)$ = The price function of the processed product, G_p = Goal set for the price for the processed products, U^+s, U^-s are the non-negativity deviation from the goal setting.

4 RESULTS AND DISCUSSION

SOCIAL-ECONOMIC CHARACTERISTICS OF THE RESPONDENTS

Characteristics of respondents interviewed have important social and economic implications towards factors influencing cassava production and consumption. For example, family characteristics such as age usually influence the quantity of the agricultural output. Therefore, this section describes the characteristics of sampled respondents, focusing on age, gender, household size and education level.

AGE OF THE RESPONDENTS

The distribution of farmers according to age is presented in Table 1. Results show that majority of the respondents (67.5%) were above 36 years of age and people with active age (17 to 55 years) constituted 80.8% of total respondents. Meanwhile, respondents aged above 55 years were 19.2%. Basing on the information above, it is clear that in the study area the working force is available and able to work in agriculture as their main economic activity but large percentage (48.3%) of the sampled cassava farmers are falling in the age of 35 to 55 years (Table 1).

GENDER OF THE RESPONDENTS

Result in Table 1 show that, about 63% of the respondents were male and the remaining 37% were female. Skewed results were expected since men are the household heads to whom the interview was directed. As far as cassava production is concern as observed by TADENA (2004), access and use of land for cassava production is not gender biased. Either of the sexes can get involved in cassava production. There is no bias when it comes to providing access to farmland for women. Likewise, there are no important cultural beliefs and practices that are likely to affect the development of cassava (Table 1). The results also show that 32% and 38% of the men and women respectively within sampled households were using mechanized cassava processing technology.

Table 1: Social-economic characteristics (n=120)

Variable	Categories	Frequency	Percentage
Age	17-35	39	32.5
	36-55	58	48.3
	>55	23	19.2
Gender	Male	75	62.5
	Female	45	37.5
Household size	1-3	28	23.3
	4-6	71	59.2
	>6	21	17.5
Education level	No formal education	22	18.3
	Standard four (iv)	3	2.5
	Primary education	74	61.7
	Secondary education	21	17.5

HOUSEHOLD SIZE OF THE RESPONDENTS

Results in Table 1 shows that about 23.3% of the households have 1-3 members and 59% of the household sizes have members ranging between 4 and 6 and only 17.5% of the sampled households were above 6 household's members.

Therefore, majority of the households (76.7%) have 4 members and above, which signifies that there is enough work force due to the fact that majority of population in the study area fall in the age of 17-55 years.

EDUCATION OF THE RESPONDENTS

Education is one of the factors that influence cassava production. A farmer with formal education is likely to be innovative or adoptive to new technologies than a farmer with no formal education whereas other factors remain constant. The study revealed a moderate rate of literacy in the study area. Results on level of education showed that respondents in the study area have attained formal education. The majority of sampled household heads in the study area (61.7%) and (17.5%) had attained primary education and secondary education respectively. These findings support the observation by the assessment of agricultural marketing information needs study (URT, 2004), which found that there is a large number of farmers with primary education and above. This shows that, the introduced cassava processing technology could be easily adopted in the study area because most of the farmers have formal education although the adoption depends with the efficiency of the technology and its profitability to the farmers.

PROJECTION OF FUTURE PRODUCTION OF CASSAVA RESULTING FROM MECHANIZED CASSAVA PROCESSING

The projection for the future production in cassava of the two districts (Muheza and Kibaha) was done by using goal programming approach. Muheza district is superior to Kibaha district in cassava production, but the total production of the two districts was taken as the bench mark for future projection for cassava production. According to the respective District Agricultural and Livestock Development Officers (DALDO), the production of Muheza and Kibaha districts were estimated at 75 000 and 5 000 tonnes, respectively which make a total of 80 000 tonnes.

The study categorised production into two categories, that is sweet and bitter varieties of cassava, and results of production found to be with a proportionality of 5:3 respectively. According to this proportionality, the sweet varieties had production of about 50 000 tonnes and about 30 000 tonnes for the production of bitter varieties. This shows that, sweet varieties are more produced than bitter varieties due to their immediate consumption.

FORMATION OF COEFFICIENT MATRIX FOR CONSTRAINTS

Any maximization function must involve constraints; the constraints used to maximize production of cassava in this study were consumption of cassava, varieties for cassava production, access to the market for cassava products, costs of cassava processing and prices for processed cassava. Therefore the coefficient matrix formed was as follows: the consumption of bitter and sweet varieties ratio was 1 500:2 000 tonnes and the goal or targeted value for this was set at 30 000 tonnes per year per village with the positive and negative deviations of 500 tonnes.

The second constraint was variety, in good management (agronomic) bitter variety can produce up to 8 tonnes per acre and 7 tonnes for sweet variety, which in combination they can produce 15 tonnes, therefore the goal or targeted value set for that one was 18 tonnes with a positive deviation and negative deviation of 3 tonnes. The important concept to bear in mind here is that, bitter varieties produce more yield than sweet varieties.

The third constraint was access to the market. Table 2 shows that the constraint has 400:500 ratio of bitter and sweet variety accessed to market respectively, with a goal or targeted value of 20 000 tonnes from a bench mark of 15 000 tonnes. Also the positive and negative deviations were 5 000 tonnes.

The fourth constraint was cost of processing. The observation made shows that there was no difference in cost of processing of neither bitter varieties nor sweet varieties and thereafter it was estimated to cost 150 TZS per kilogram which implies 150 000 TZS per tonne as processing cost. The positive and negative deviations were 50 000 TZS (Table 2).

Table 2: Coefficient matrix for optimization of cassava production

Constraints	Bitter variety in tonnes (Q_1)	Sweet variety in tonnes (Q_2)	Positive deviation from targeted value(U^+)	Negative deviation from targeted value (U^-)	Total
Consumption (t)	1 500	2 000	500	500	30 000
Variety productivity (t/acre)	8	7	3	3	18
Access to market (t)	400	500	5 000	5 000	20 000
Cost of processing (TZS/kg)	150	150	50 000	50 000	150 000
Price per tonne (TZS)	500	500	100 000	100 000	700 000
Total for each variety	30 000	50 000	-	-	-

The last constraint was the price of the processed products. The cassava flour processed from bitter varieties is more preferred, than the sweet cassava flour. This caused the price of bitter cassava flour to be higher than sweet cassava flour price. The bitter cassava flour was TZS 500 per kilogram whereas TZS 500 was the price for sweet cassava flour. Therefore, taking the maximum price per tonne, a cost of about TZS 500 000 with a positive and negative deviations of TZS 100 000. This information is summarized in the Table 2 above.

Values of the program

The coefficients matrix formed ready for maximization process was estimated using linear programming software. Results indicates that the pivot value was 7.00 and the optimum solution found after first iterations and the maximum value for cassava production was 128 571.4 tonnes, which is the projection for future production of cassava for the two districts.

Results revealed that the disposal or slack variables were consumption, access to the market, processing costs and price of the processed products. Since the maximization of cassava production realistically did not use the entire quantity of each constraint available, provisions must be made for the non-use constraints in the final plan. These variables allow the non-use or changes to be made.

Furthermore, the objective of the study was to maximize production subject to those constraints mentioned above, with a goal or targeted value to be achieved. Therefore, the final (optimal) plan was to produce sweet varieties 2.57 times the previous production, setting aside the bitter varieties. This is due to reasons that, many farmers do not feel like to produce bitter varieties because the varieties take long time to mature in the field and tedious work in processing.

5 Conclusion and recommendation

The introduction of mechanized processing technology has resulted into the change in cassava consumption behaviour, hence increase in demand of the product. This has further stimulated production of cassava in the study areas. Based on goal programming approach the projection of the future production of cassava will be 128 571.4 from 80 000 (current production) tonnes per year. This is an increase of 60.7% per year.

Basing on the above conclusion it is highly recommended that the farmers have to be informed on the growing demand of the mechanically processed cassava products, thus the need to meet this demand. The processors, businessmen, government and others stakeholders of the cassava sub sector have to be highly coordinated with the farmers and provide the farmers with all agronomic, economic and technical supports so as to sustain the production of cassava and meet the growing demand of the products.

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