Efficiency of Watermelon (Citrullus lanatus Thunb.) Production Technologies in North Central Nigeria

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Abstract — This study is aimed at determining the efficiency of watermelon production technologies using profit model and Data Envelope Analyses. Primary data through structured questionnaire and interview were administered to 280 farmers. The result of the study shows that Conventional Watermelon Production (CWP) was more profitable N252,485.4 per ha compared to Scientific Watermelon Production (SWP) at a profit of N237,070.0 per ha. The energy use efficiency ratio of CWP at 1.49 was also higher compared to SWP which was 1.03. However, the output from scientific farms of 3,014 pods as well as the scale efficiency of 0.81 was higher compared to the output and scale efficiency for the conventional farms of 2,567 and 0.65 respectively. The result also indicates that scientific production system had a higher technical efficiency using Charnes, Cooper and Rhodes (CCR) model 0.73 and Banker, Charnes and Cooper (BCC) model 0.89 compared to conventional watermelon production technique with CCR and BCC of 0.59 and 0.73 respectively. The study also revealed that the scientific watermelon production system was more technically efficient and the output was higher than the conventional farming. Despite this, there is need to critically find a way of increasing energy parameters and technical efficiency in both production systems to move closer to energy optimum and efficiency frontier. This could be achieved by the integration of the two production systems to achieve low cost and efficient scientific inputs usage. On the other hand, watermelon farmers could also shift to semi-mechanized farming for higher output and to be more technically efficient.

Keywords: Pure technical efficiency, scientific, specific energy, watermelon.

1 INTRODUCTION

Energy is considered as an indispensable force and vital to virtually all economic activities and indeed agricultural development. A supply of clean, secure, efficient, equitable, affordable, reliable and sustainable energy services that have minimal impact on the environment is vital to Nigerian future prosperity. The agriculture, energy and production nexus are very close. Albeit, agriculture itself is a source of bio-energy and organic manure which is derived from biological materials such as wood, agricultural crop wastes and dung. However, energy is widely regarded as a propelling force behind production and indeed agriculture (Oladimeji et al., 2016a). According to Nabavi-Peleasarai et al. (2016), energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an improved standard of living. In most countries, efforts towards food production have encouraged increasing energy inputs to maximize yields, minimize labour-intensive practices, or both (Esengun et al., 2007). Unlike many developing countries, efforts towards food production seem to be greater than the population growth in most developed countries. Suffice to note that the development and exploitation of energy for agricultural production in most developing countries including Nigeria have been skewed in favour of non-renewable energy sources- chemical and inorganic fertilizer, fossil fuels mainly petroleum products, and of recent natural gas- than bio-energy and organic manure (Oladimeji et al., 2016a). Energy services are fundamental to achieving sustainable agricultural development. Despite her enormous energy resource potentials and endowment, Nigeria government could not explore and provide affordable energy for majority of its citizenry and poverty remains critical developmental challenges. Therefore, the country must explore more bio-energy and organic manure for agricultural production activities to complement and checkmate the excessive effect of chemical fertilizer on the environment. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals, and people. In few developing countries, provision of adequate, affordable and reliable energy services has been sufficient to reduce poverty and improve standards of living.

1.1 PROBLEM STATEMENT

Watermelon (Citrullus lanatus) is a member of the cucurbit family (Cucurbitaceae). The crop is cultivated in small hectares of land in both humid and savanna ecological zones mostly for commercial activities in northern part of Nigeria. It is imperative to note that an efficient use of energy in watermelon production is required to produce sustainable food. Given the sheer size of Nigerian cultivable land estimated at 61 million ha and about two-third of 160 million active labour force involved in agriculture, availability of modern farming technologies will ultimately enhance energy utilization and sustainable increases in food production and raw material for the agro-food industries not only for Nigeria but also for exports to other countries (Oladimeji et al., 2016b).

In the past, several authors have applied varieties of efficiency methods both parametric and non-parametric for measuring the efficiency and benchmarking of decision making units (DMUs) and more closely find better and more appropriate technological methods to adopt to
protect energy expenditures for crop production. Some of these studies: Banaeian and Namdari (2011), Namdari, (2011), Oladimeji et al. (2016a) and Nabavi-pelesaraei et al. (2016) demonstrated that energy input-output analysis in agricultural systems has been widely used to assess efficiency which leads to increased production and productivity, resource savings, efficiency gains and invariably generate higher income (poverty alleviation) and enhance food security. Thus, the aims of this research are to:

(i) determine the profitability of watermelon production under conventional and scientific technologies,

(ii) assess inputs and output energies in watermelon production technologies, and

(ii) estimate the efficiency of the two technologies in watermelon production in North Central Nigeria.

2.0 RESEARCH METHODOLOGY

2.1 STUDY AREA

The study was conducted in North Central Nigeria which comprises of 6 States, Benue, Kogi, Kwara, Nasarawa, Niger, Plateau, and the Federal Capital Territory Abuja. North Central Nigeria covers areas between latitudes 7°45ʹ N and 9°30ʹ N and longitudes 2°30ʹ E and 6°25ʹ E. with mean annual rainfall that ranges from 780 mm to 1500 mm. The rain is concentrated between the months of April and October. The mean annual temperature ranges between 31.5°C and 35°C. Kwara State has a land mass of about 32,500 sq. Km., a projected population and farm families in 2016 to be about 3.2 million and 316,700 respectively and an average density of about 94 persons per sq. km. Niger State has a land mass of about 76,000 sq. Km, with the State population and average density per sq. km projected in 2016 to be about 5.5 million and 66 respectively.

2.2 DATA COLLECTION AND SAMPLING PROCEDURE

The study was based on primary sources of the data gathered by field surveys on watermelon production through questionnaires and interviews. Specifically, it focused on data of input and output as well as energy usage. Classification of watermelon farmers was based on stratification of farmers into two groups: majorly conventional and scientific watermelon farmers. Majorly conventional watermelon farming consists of farmers who primarily made use of organic manure and other conventional management practices such as manual weeding and tillage. Scientific watermelon farming comprises of farmers who adopted mostly modern and scientific management practices such as chemical fertilizers, herbicides, hybrid seeds, knapsack sprayer and owned or rented machinery such as tractor for ploughing and harrowing. The sampling procedure was based on a three stage household sampling survey. Kwara and Niger States were purposefully chosen largely due to dominant of watermelon farmers in the areas. In addition, Kwara Stat lies in two eco-ecological zones; the derived and the Guinea savanna and Niger State though share the Guinea savanna characteristics (only) with other North Central States, but chosen because the land mass (76,469,903 km2) is about 10% of the total land area of Nigeria or 57% of that of North Central States, out of which about 85% is arable (NPC, 2006). Thereafter, twenty eight villages comprising 12 and 16 each from Kwara and Niger States respectively were random selected. Then, 10 farmers were randomly selected from each of the villages to make a total of 280 farmers, stratified into 91 conventional and 189 scientific farmers.

2.3 MODEL SPECIFICATION

The energy input output analysis used standard energy conversion of previous studies cited by Namdari, (2011), Banaeian and Namdari, (2011), Oladimeji et al. (2016a) that obtained energy equivalents of unit inputs (Mega Joule) by multiplying inputs with the coefficients of energy equivalent.

Energy use efficiency, energy productivity and specific energy for watermelon crop production were also calculated on per hectare basis using the equations suggested in literature (Namdari, 2011 and Nabavi-pelesaraei et al. (2016a) as follows:

Energy use efficiency $\eta_u = \frac{E_{\text{output}}}{E_{\text{input}}}$ (1)

Energy productivity $\eta_p = \frac{M_{\text{output}}}{E_{\text{input}}}$ (2)

Specific energy $\eta_s = \frac{E_{\text{input}}}{M_{\text{output}}}$ (3)

Net energy $= E_{\text{output}} - E_{\text{input}}$ (4)

Data envelopment analysis (DEA) involves the use of linear programming methods to construct a non-parametric piecewise surface over the data for measuring the efficiency and benchmarking of decision making units (DMUs). In addition, DEA is a data-driven frontier analysis technique that floats a piecewise linear surface to rest on top of the empirical observations. DEA models are broadly divided into two categories on the basis of orientation: input-oriented and output-oriented. On the other hand, as energy inputs in agriculture rapidly increased and accrued several benefits to farmers, these also adversely influenced the environment (Nabavi-pelesaraei et al., 2016).

Technical efficiency (TE) is basically a measure by which DMUs are evaluated for their performance relative to the performance of other DMUs in consideration. The Technical Efficiency can be defined as follows

$$TE_j = \frac{u_1y_{1j} + u_2y_{2j} + \ldots + u_my_{mj}}{v_1x_{1j} + v_2x_{2j} + \ldots + v_mx_{mj}} = \frac{\sum_{s=1}^{m} u_s y_{sj}}{\sum_{s=1}^{m} v_s x_{sj}}$$ (5)

where, $u_s$ is the weight given to output $n$; $y_{sj}$ is the amount of output $n$; $v_s$ is the weight given to input $n$; $x_{sj}$ is the amount of input $n$; $r$, is number of outputs ($r = 1, 2, \ldots, n$); $s$, is number of inputs ($s = 1, 2, \ldots, m$) and $j$, represents $j$th of DMUs ($j = 1, 2, \ldots, k$). Equation (5) is a fractional problem, so it can be translated into a linear programing problem which was adapted by Nabavi-pelesaraei et al. (2016).
Maximise $\theta = \sum_{j=1}^{n} u_j Y_{yj}$
Subjected to $\sum_{j=1}^{n} u_j y_{yj} + \sum_{j=1}^{m} v_j x_{sj} \leq 0$
$\sum_{j=1}^{n} v_j x_{sj} \leq 0$
$u_j \geq 0, v_j \geq 0$, and $(i = 1,2,3,...k)$.

Where $\theta$ is the TE. Equation (6) is known as the input oriented CCR DEA model which assumes constant return to scale (Nabavi-pelesaraei et al., 2016).

Empirical model specification for the determinants of technical efficiency is as follows:

$I_{ny} = \beta_0 + \beta_1 \ln X_{y0} + \beta_2 \ln X_{y1} + \beta_3 \ln X_{y2} + \beta_4 \ln X_{y3} + \beta_5 \ln X_{y4} + \beta_6 \ln X_{y5} + \beta_7 \ln X_{y6} + \beta_8 \ln X_{y7} + \beta_9 \ln X_{y8}$

Where subscript i refers to the observation of the ith farmers, In = Logarithm to base e, $y_i$ = Output of watermelon farmers of the ith farmers ($N$); $X_i = farm$ size in hectare ($N$); $X_2 = seed$ (kg/ha); $X_3 = Organic$ fertilizer for conventional or chemical fertilizer for scientific (kg/ha) and $X_4 = labour$ in man-days per ha. $V_i$ and $U_i$ are error terms. Note: Adult labour equivalent was generated from Organization for Economic Cooperation and Development (OECD) Scale as follows:

$AE = 1 + 0.7 (N_{1\text{adult}} - 1) + 0.5N_{2\text{children}}$ (7)

Where, AE represents the TE equivalent, $N_1$ represents the number of adult aged 15 and above and $N_2$ is the number of children aged less than 15.

Hypothesis:
(i) There is no significant difference between profit of conventional and scientific watermelon farmers
(ii) There is no significant difference between technical efficiency of conventional and scientific watermelon farmers.

3 RESULTS AND DISCUSSION
3.1 PROFITABILITY ANALYSIS

The results of profitability analysis are presented in Table 1. The result revealed that labour accounted for 60.4% of TVC and 53% of TC in conventional watermelon production and 59.1% and 50.6% respectively in scientific watermelon production. Furthermore, inorganic chemicals gulped over 34.8% of TVC and about 30% of TC in scientific production system. However, both TC and Gross Margin (GM) or Net Margin (NM) in Table 1 shows that conventional watermelon farming was less costly and more profitable compared to scientific farming. In fact, average net margin was about ₦15178 higher among the conventional unit than those of scientific farming. The result also revealed that profit margin and return on investment performed better in conventional farming (68.5% and 3.17) compared to scientific farming with 62.2% and 2.65 respectively. The net margin between the two production systems was significantly different at 1% level of probability. Based on the findings, as well as indicators computed, it can be concluded that both farming systems are profitable, however, conventional watermelon farming were found to be more profitable due to higher price tag in the study area.

3.2 INPUT AND OUTPUT ENERGIES IN WATERMELON PRODUCTION TECHNOLOGIES

The results of input and output energies in watermelon production technologies per ha presented in Table 2 revealed that conventional system had TEI of 6552 MJ ha$^{-1}$ while scientific system had 11146 MJha$^{-1}$. The most energy consuming inputs in conventional system were FYM, labour and irrigation. On the contrary, chemical fertilizers, machinery and diesel were the most energy consumed in scientific system. The result also revealed that the energy use efficiency and energy productivity for conventional production were 1.49 and 0.78 kgMJ$^{-1}$, while that of scientific system were 1.03 and 0.54 kgMJ$^{-1}$ respectively.

The energy productivity implies that 0.78 kg of watermelon was obtained per unit energy (MJ) in conventional unit which was higher than 0.54 kg per MJ obtained in scientific unit. The marginal difference could be largely due to high consumption of diesel by the automotive machines. The energy use efficiency ratio of conventional (1.49) indicates high energy use efficiency compared to the 1.03 of scientific system which was in line with a priori expectation and report of Namdari, (2011). The specific energy and net energy of conventional unit was 1.28 MJkg$^{-1}$ and 3202.6 MJha$^{-1}$ and that of scientific was 1.85 MJkg$^{-1}$ and 307.2 MJha$^{-1}$ respectively. Thus, a specific energy of 1.28 for the conventional and 1.85 for the scientific means that either of energy is required to produce a unit of watermelon.

Table 1: Differential average cost and return per ha in watermelon production

| Variables          | Conventional (68.5%) | Scientific (53.17%) |
|--------------------|----------------------|---------------------|
| Labour             | 23780.00             | 1390.00             |
| Fertilizer         | 7300.00              | 153000               |
| Machinery          | 13900.00             | 139000               |
| Diesel             | 35700.00             | 52700.00             |
| Total Cost         | 67450.00             | 164100               |
| Profit             | 31450.00             | 87100.00             |
| Profit Margin      | 61.7%                | 62.2%                |
| Return on investment | 2.9%                | 2.65%               |

Field survey, 2014/15; note labour include both family + hired; *** denote 1% level of significant.

3.3 EFFICIENCY ESTIMATION USING DATA ENVOLPMENT ANALYSIS (DEA) TECHNIQUE

Results in Table 3 revealed that both technical efficiency using CCR model and pure technical efficiency using BBC model of conventional production (0.59 and 0.77 respectively) were less compared to scientific production system (0.73 and 0.89 respectively). Furthermore, 19 and 31 farmers in scientific system could shift on CCR and BCC frontier respectively. Therefore, farmers in scientific system had considerable use of energy and production (kg/ha) in agreement with Banaeian and Namdari, (2011).
Table 2: Inputs and output energy under different watermelon production technologies

| 1. Inputs Items | Group 1 (inorganic) | Group 2 (inorganic) |
|-----------------|---------------------|---------------------|
|                  | Energy Equivalent (MJ Unit-1) | Group 1 (inorganic) | Group 2 (inorganic) |
| H. labour ha-1  | 9.96 (Oladimeji et al., 2016a) | 763.5 | 489(22.9) | 58.6 | 1151(10) |
| Machinery (ha)  | 27.7 (Oladimeji et al., 2016a) | 10.2 | 659.9(9.3) | 28.9 | 18132(16.3) |
| Herbicide (L)   | 12.0 (Tabatabaeeafar et al., 2013) | 3.5 | 4202(4.3) |
| FYM (kg)        | 0.30 (Tabatabaeeafar et al., 2013) | 4665.5 | 1846(29.6) |
| Nitrogen (kg)   | 0.66 (Mohammadi et al., 2008) | 45 | 29836(7) |
| Phosphate (kg)  | 11.99 (Eseni et al., 2011) | 10 | 3283(2) |
| Potassium (kg)  | 6.7 (Eseni et al., 2011) | 10 | 2011(8) |
| Diesel (L)      | 0.29 (Mhdossami et al., 2008) | 17.3 | 974.2(14.9) | 43.8 | 24860(22.1) |
| Irrigation H2O (L) | 388.5 (Tabatabaeeafar et al., 2013) | 1890 | 1976(16.1) |
| Seed (kg)       | 0.15 (Tabatabaeeafar et al., 2013) | 1.2 | 239.0(15) |
| FYM (1000)      | 6552(300) | 11246(100) |
| Note: TEI denote T total energy input; FYM, Farm Yard Manure, l/d, labour/day = average 8 hours; a pod of watermelon average = 2 kg per one.

The average technical efficiency (resource use) provided information about the potential resource savings that could be achieved while maintaining the same output level. The scale efficiency of farm showed that scientific farmers (0.81) were more efficient implying that the farmers could expand their production output further by a relatively high margin of 0.22 by adopting more superior and improved techniques and technology of the best practiced. Table 4 shows that NRE (73.8%) and indirect energy (51.8%) in scientific system were higher compared to conventional farming. Despite this, there is need to critically find a way of increasing energy parameters and technical efficiency in both production systems to move closer to energy optimum and efficiency frontier. This could be achieved by the integration of the two production systems to achieve low cost and efficient scientific inputs usage. On the other hand, watermelon farmers could also shift to semi-mechanized farming for higher output and to be more technically efficient.

Table 3: Frequency distribution of efficiencies of watermelon farmers under different groups

| Efficiency Score | 0.0 50 | 0.5 1.0 | 0.5 1.0 | 1.0 1.5 | 1.0 1.5 | 0.5 1.0 | 0.5 1.0 | 0.5 1.0 | 0.5 1.0 | 0.5 1.0 | 0.5 1.0 | 0.5 1.0 | 0.5 1.0 |
|------------------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| CCR              | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  | 0.59  |
| Model            | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  | 0.73  |
| TEE              | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  | 0.86  |
| BCC              | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  | 0.95  |
| Model            | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  | 0.99  |
| TEE              | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  | 0.93  |
| Average          | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  | 0.57  |
| Scale            | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  | 0.81  |
| Efficiency       | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  | 0.80  |

Source: Field survey, 2014/15; Note: TEI denote Total energy input; FYM, Farm Yard Manure, l/d, labour/day = average 8 hours; a pod of watermelon average = 2 kg per one.

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