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Agricultural Multivariate Stratified Sample Survey with Applications to a Food Supply System

(The Case of Damota District, North Omo Administrative Region)

by
GENENE ZEWGE

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in partial fulfillment of the requirements
for the Degree of
Master of Science in Statistics
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TO THE MEMORIES OF MY MOTHER

YESHI DEJENIE

and

OUR COMMON FRIEND

OSMAN GAIRAR

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ABSTRACT

The population studied comprises the agricultural households of a community in Damota district which is found in the North Omo administrative region. It was stratified by using the agro-ecological factor as the stratifying variable into three strata. Thus, the three strata arrived at in the process were the "Dega", "Kolla", and "Woyna Dega" agro-ecological zones in the research area.

In the case where the study variables of interest are greater than one in a stratified sample survey, the usual optimum (Neyman) allocation method cannot be applied directly since what is best for one study variable may not necessarily be best for the other. Thus, other alternative techniques developed to go about this problem have been compared. These include the compromise, chatterjee as well as proportional allocation. Other methods which involve non-linear programming techniques were also reviewed.

The data on the study variables which were believed to be indicative of the food supply system of the area were collected These included the family size, acreage, production, expenditure, reserves and purchases of the households. This was done through interviews carried out by going to the sampled households. Prior to the conduct of the final survey, however, a pilot survey was undertaken which covered fifty households from each stratum. This was done in order to obtain the necessary information to estimate the stratum variances which were required for sample allocation purposes. The sample size

determination was also done scientifically by similarly using the data from the pilot survey as well as the approved budget of the survey and additional cost estimates.

In addition to the above, anthropometric measures of children under five years of age were collected for the purpose of studying the nutritional status of the population considered.

CHAPTER I

INTRODUCTION

1.1 General

Reliable data on various socio-economic activities are required for the formulation as well as evaluation and monitoring of development plans and appropriate decision making. The low level of development reached by developing countries reflects very seriously on the data collection, processing and timely dissemination capabilities of these countries which is manifested in the national statistical organizations that are often unable to address their data requirements due to financial as well as trained manpower and infrastructure constraints. As agriculture is the predominant activity in these countries, they have tried to accord due priority to the development of agricultural statistics. FAO, UNDP, UNICEF and the UN Statistical Office have made considerable efforts in this regard by providing technical assistance in terms of direct advisory services to such countries as well as by organizing seminars and workshops to facilitate exchange of views on methodologies and related experience. They also contribute to the statistical development needed in this group of countries by the preparation of technical publications. They, in addition, provide other financial and data processing support to the developing countries. The programmes for the different world censuses of agriculture are efforts in this direction.[1] Ethiopia has not

[1] The fourth decennial programme launched by FAO, the 1980 census round, (i.e. national censuses to be undertaken during the decade 1976-85) and its predecessors were efforts to help developing countries in the identification of the minimum list of data to be collected as well as to allow international comparability of such data collected. In addition, they are also involved in

undertaken a census of agriculture to date [CSA (1983)]. Different survey methods are currently used by the CSA to obtain estimates on agricultural production as well as other variables of interest [CSA (1983)]. Primary data collection about a population of interest can be done using censuses and/or surveys.

The advantages of sampling over complete enumeration are manyfold provided that the estimates obtained by applying the appropriate sampling design serve their purpose. The advantages include, inter-alia, reduced cost; greater speed; greater scope; and greater accuracy [Cochran (1977)]. These advantages are especially more pronounced in a country where resources, both human and material, are lacking. There are many sampling designs and yet a variety of procedures have been developed over the past. These include simple random sampling; stratified sampling; systematic sampling; cluster sampling; subsampling; double sampling; sampling with varying probabilities, etc. [Cochran (1977), Des Raj (1976), Kish (1950), Som (1973), Hansen, Hurwitz and Madow (1953)].

The present study relates to stratified sampling. This method is one in which the population, which according to various considerations [2] is heterogeneous, is divided into subpopulations, N_h, ($h = 1,2, \dots, L$; where L is the total number of subpopulations) which are non-overlapping and homogeneous within themselves such that their union produces the total population being considered (i.e., $N_1 + N_2 + \dots + N_L = N$). Each subpopulation

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developing and improving agricultural statistical systems in countries where they are lacking or inadequate.

[2] These include prior knowledge of the important factors of heterogeneity in the populations.

arrived at in such a manner is termed a stratum. If the procedure of selection of the sample units in the strata is random then the method is referred to as stratified random sampling. The advantages obtained by adopting stratification in a heterogeneous population include the gain in precision in the estimates obtained from the sample about the population characteristics.

The various aspects of problems confronting the survey statistician in applying the theoretically developed tools of survey sampling, in particular in the area of stratification, have been dealt with in various areas of human endeavour and their results have been published in various scholarly publications in the field of statistics. The problems that arise in these areas include, inter alia, the determination of the optimum number of strata required, the identification of the appropriate stratifying variable, the determination of the sample size and the appropriate sizes of units to be included in the sample from the various strata.

As clearly cautioned in many instances and in various publications by many prominent scholars in the field, the survey statistician will be forced to take a decision regarding the number of units to include in the sample at one stage or another of the survey planning. And this actually involves the prior decision on the degree of accuracy of the estimates required from the survey as well as the funds available for undertaking the survey.

The stratum variances are eventually required in the determination of the stratum sample sizes. Four ways of estimating the population stratum variances when they are not known have been recommended: (i) taking the samples in two steps; (ii) from the results of a pilot survey; (iii) from a previous sampling of the same or a similar population; and (iv) by guesswork about the structure of the population assisted by some mathematical results [Cochran (1977)].

There is no simple rule of thumb to decide the sample size, n, and the various possibilities to be adopted in this regards will be elaborated in Chapter 2.

1.2 Background

Ethiopia, a least developed country (LDC), [3] is a predominantly agrarian economy. Over 90 per cent of the population live in rural areas and derive their livings from activities related to agriculture. The agricultural sector is mainly subsistent and is characterized by its dependence on primitive technology and rain-fed cultivation which affect the productivity levels of farmers, making them vulnerable, among other things, to drought-generated famine. The famines of 1974, 1984-85, and 1987-88 are vivid examples of the serious magnitudes that famine can reach in terms of its claims on human lives as well as livestock. The

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[3] According to the UN's definition, i.e. based on the most recently used criteria, LDC's are countries with the following characteristics: (i) these are countries with Gross Domestic Product per capita of up to US$427; (ii) with a low literacy rate (20 per cent or less of the population old enough able to read); and (iii) a low proportion of manufacturing in total output (share of manufacturing in total Gross Domestic Product of 10 per cent or less).

deterioration of socio-economic conditions in general and the agricultural situation in particular, in the country has been captured in the following data from the World Bank. Cereals imports have climbed from 118 thousand tons to 609 thousand tons, which exhibited a 14.6 per cent average yearly jump. The food aid figures in cereals also show a big jump from 54 thousand tons in 1974/75 to 570 thousand tons in 1985/86. The proportions of children under the age of five was 19 per cent in 1987 and infant mortality was registered to be 155 per 1000 live births, the highest registered in the world. Life expectancy in the country was at the level of 47 years in 1987. [4]

The problem of famine is further aggravated in the country by civil strife, which has peaked recently, structural deficiencies and other compounding problems. Thus, caught in a web of complicated problems, which wiped out a substantial proportion of its population, the Government in 1977 put in place an Early Warning System (EWS) in an effort as a provisional measure to forestall unpreparedness for major food deficiency crises. The EWS assesses the food supply situation with a view to indicating possible threats of famine to enable appropriate intervention.

The EWS mostly uses qualitative and subjective information collected from different groups supplemented with information on food and livestock prices and rainfall data. These are mainly based on the Rapid Rural Appraisal technique where information is collected through group discussions; eye estimates and interviewing of key persons in the areas.

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[4] IBRD, Sub-Saharan Africa, From Crisis to Sustainable Growth, a long-term perspective study, Washington D.C., 1989.

Although the technique used by the RRC serves in providing needed information on the threats of famine, there is room for improvement of the methods of data collection and analysis.

Although some methodologies of stratified sampling have been used in the country much remains to be done in terms of comparing competing procedures especially in the case of multivariate considerations.

1.3 Objectives

In light of the foregoing, the study aims:

(i) To compare different multivariate stratified sample designs with respect to optimum allocation problems;

(ii) To strengthen the EWS and the disaster area assessment system of the country by encouraging the use of multivariate stratified sampling techniques for collection of data in a disaster area; and

(iii) To conduct a nutritional status survey of children aged twelve to sixty months in the sampled population as an indicator of food defficiency resulting in malnutrition;

(iii) To contribute to the development of improved capabilities of data collection and survey design methodologies for a disaster area assessment.

The present study then endeavours to bridge the existing gap with particular concern to the food supply system of the area as well as the nutritional status appraisal.

The plan adopted in the study is the following. Chapter II introduces the bulk of the theory applied and reviews the relevant literature that were available at the time of the study. The sample size determination and allocation to the different strata from pilot survey results will also be discussed in the same chapter. Chapter III gives a full account of the surveys undertaken with a background of the area studied and some remarks on the possible sources and control of non-sampling errors in the survey. The survey results are analyzed in Chapter IV and Chapter V contains the conclusions and recommendations of the study.

CHAPTER II

METHODOLOGICAL BACKGROUND AND ALLOCATION OF SAMPLE TO STRATA

2.1 Introduction

To benefit from stratified sampling procedures, the survey statistician is required to take appropriate decisions on the four questions related to design. These are the following:

(a) the choice of the stratifying variable;

(b) the choice of the number of strata;

(c) the determination of the method to be used to stratify the population; and

(d) the allocation of the size n_h of the sample to be taken from the h^{th} stratum.

The problem to be addressed in this paper is the allocation of the h^{th} stratum sample sizes, n_h, when the variables of interest are greater than one.

With a single character under study and for a given sampling procedure, optimum allocation is well defined and it is that which minimizes the cost of the survey for a desired precision or minimizes the variance of the sample estimate for a given budget of the survey.

In stratified random sampling the value of the stratum sample sizes, n_h, are determined by the survey statistician. The decision involves either minimizing the variance, V ($\bar{y}_{st}$) for fixed cost or minimizing the cost for fixed variance, V ($\bar{y}_{st}$) (Cochran (1977)). If one variable is considered optimum allocation (Neyman allocation) is applied to determine the elements to be included in the sample from each stratum in the following manner:

$$n_h = \frac{nW_hS_h}{\sum_{n=1}^{L} W_hS_h} \qquad (2.1)$$

Although such an optimum allocation in the case of a single variable of interest is immediately solved as given in (2.1) above, problems of optimum allocation arise when the case involves many variables to be sampled from each stratum since the best or optimum allocation for one item may not necessarily be best for another [Cochran (1977)]. [5] In such a case, some compromise must be looked for.

Prior to discussing the methods of determining the optimum stratum sizes using various methods developed in the theory of statistics, the method of determining the total sample size, n, becomes a necessity. The paper, therefore, first reviews the basic methods developed in this regard [6] prior to discussing the different methods used when Neyman's single item optimum allocation falters due to many items to be sampled from each stratum.

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[5] In a specialized surveys the items to be collected may be highly correlated and thus the optimum allocation results of the sample sizes may not differ greatly.

[6] Only concerned with stratified sampling; thus does not deal with other methods.

2.2 Determination of total Sample Size, n

(a) For Optimum Allocation in a univariate setup

(i) This method arises when the cost of the survey is fixed and the cost function is assumed to follow a linear form of the following type:

$$C = c_o + \sum_{h=1}^{L} c_h n_h \qquad (2.2)$$

where,

C = the total cost of the survey;

c_o = the overhead cost;

c_h = cost per unit in stratum h;

n_h = the h^{th} stratum sample size; and

L = the total number of strata.

If one substitutes the optimum values of n_h in (2.1) and solves for n one gets the following formula for the total sample size:

$$n = \frac{(C - c_o) \sum_{h=1}^{L} (N_h S_h / \sqrt{c_h})}{\sum_{h=1}^{L} (N_h S_h \sqrt{c_h})} \qquad (2.3)$$

(ii) This method involves fixing the variance. Thus if variance is fixed to be V_o, then substituting the optimum n_h in the formula for $V(\bar{y}_{st})$ [7] one obtains the following formula for n:

$$n = \frac{(\sum_{h=1}^{L} W_h S_h \sqrt{c_h}) \sum_{h=1}^{L} W_h S_h / \sqrt{c_h}}{V_o + (\frac{1}{N}) \sum_{h=1}^{L} W_h S_h^2} \qquad (2.4)$$

(iii) This is arrived at if one assumes the cost per unit in all the strata is the same. Thus the cost function (assumed to be linear) becomes as follows:

$$C = c_0 + c\,n \qquad (2.5)$$

where c is the cost per unit and is similar in all the strata.

[7] The formula for the variance of y_{st} is given as follows:

$$V(\bar{y}_{st}) = \sum_{h=1}^{L} \frac{W_h^2 S_h^2}{n_h} (1 - f_h) = \sum_{h=1}^{L} \frac{W_h^2 S_h^2}{n_h} - \sum_{h=1}^{L} \frac{W_h^2 S_h^2}{N_h}$$

Therefore,

$$n=\frac{C-C_o}{c} \qquad (2.6)$$

In such a case, optimum allocation for fixed cost reduces to optimum allocation for fixed sample size.

(b) For other types of allocation

It is assumed that the estimate has a specified variance, V. [8] Thus, using estimates of the stratum variances S_h^2 and letting $n_h = w_h n$ by choosing the w_h the variance, $V(\bar{y}_{st})$ will then be given by the following formula:

$$V=\frac{1}{n}\sum\frac{W_h^2 S_h^2}{w_h}-\frac{1}{N}\sum W_h S_h^2 \qquad (2.7)$$

with $W_h = N_h/N$. This gives the following general formula for the sample size n:

[8] If the margin of error d is specified, then $V = (d/t)^2$ where t is the normal deviate corresponding to the allowable probability that the error will exceed the desired margin.

$$n=\frac{\sum \frac{W_h^2 s_h^2}{w_h}}{V+\frac{1}{N}\sum W_h s_h^2} \qquad (2.8)$$

The following special cases of (2.8) are preferred for their computational convenience:

(i) Presumed optimum allocation

Fixing n and making w_h proportional to $W_h s_h$ the following formula for n is obtained:

$$n=\frac{(\sum W_h s_h)^2}{V+\frac{1}{n}\sum W_h s_h^2} \qquad (2.9)$$

(ii) Proportional allocation

Taking $w_h = W_h = N_h/N$, one first obtains n_o, the initial sample size:

$$n_o=\frac{\sum W_h s_h^2}{V} \qquad (2.10)$$

Then use n_o to obtain the value of n:

$$n=\frac{n_o}{1+n_o/N} \qquad (2.11)$$

2.3 Optimum Allocation Problems in a Multivariate Set-up

2.3.1 General Basis

If the variables under consideration are closely related, Neyman's allocation for individual variables may be applied and then the average of these values taken as a compromise as noted earlier. However when the variables under consideration are not related, the individual Neyman allocations differ widely and no compromise is possible. As a result various authors have developed methods of sample allocation to strata that require mainly the use of mathematical programming techniques.

Dalenius (1953, 1957) was the first to suggest the application of both linear and non-linear programming methods to go about the problem.

Yates (1960) suggested two methods. The first method was one that expressed the loss in precision that would be incurred by using the estimate of a given sample size in monetary terms. Then the method used was to minimize the total cost of the survey assumed to be of the following nature:

$$C(n) = C_o + \Sigma\, c_h\, n_h \qquad (2.12)$$

and the monetary loss function:

$$L(n_h) = \Sigma\, a_j\, V_j \tag{2.13}$$

where $V_j = V(\bar{y}_{st})$ for the j^{th} variable and the a's are constants, j = 1,2, ..., J. This procedure gives the optimum stratum size as:

$$n_h = \frac{n(W_h A_h/\sqrt{c_h})}{\Sigma(W_h A_h/\sqrt{c_h})} \tag{2.14}$$

where

$$A_h = \sqrt{\sum_j a_j S_{jh}^2}$$

The second approach of Yates minimizes the total cost of the survey subject to variance restrictions of the J estimates.

The problem then may be expressed in the following way:

Minimize

$$f(n) = \sum_{h=1}^{L} (C_h n_h) \tag{2.15}$$

subject to

$$g_j(n) = \sum_{h=1}^{L} (d_{jh}/c_h n_h) - 1 \le 0, \qquad j = 1, 2, \ldots, J \tag{2.16}$$

and

$$n_h \geq 0, 1 \leq h \leq L. \qquad (2.17)$$

where $d_{jh} = C_h A_{jh} / b_j$

$A_{jh} = W_h^2 S_{jh}^2$

$W_h = N_h / N$

$b_j = A_{jo} + V_j$

$A_{jo} = \Sigma (W_h S_{j\,h}^2 / N)$

and V_j is the specified upper limit of the variance of the estimate, and

$C_h > 0$; $A_{jh} > 0$ and $b_j > 0$; are all known constants.

This problem is one in non-linear programming and since it is also a convex one, convex programming techniques may be applied to obtain the optimal solution. However, the application of this technique is not straightforward, since one has to develop algorithms for its solution or use already developed programmes with some modifications.

When no workable computer programme is available, Booth and Sedransk (1961) suggested that Yates' second problem can be approximately solved by a prior solution of Yates' first problem.

Let the loss function have the following value

$$V^* = \Sigma a_j V_j \tag{2.18}$$

where the V_j are the desired individual tolerances and the a_j are selected by making them inversely proportional to the V_j. With two variates under consideration,

$$a_1 = \frac{V_2}{V_1 + V_2} \quad ; \quad a_2 = \frac{V_1}{V_1 + V_2}$$

and

$$V* = \frac{2V_1V_2}{(V_1 + V_2)} \tag{2.19}$$

Using the above and the sample size n, the optimum values of n_h can be obtained (Cochran (1977)).

Kokan (1963) and Kokan and Khan (1967) also formulated the problem as one in non-linear programming. Their formulation took the following form:

Minimize

$$\sum_{h=1}^{L} c_h n_h \tag{2.20}$$

Subject to

$$\sum_{h=1}^{L} a_{h_j} x_h \leq v_j \quad , \qquad j=1,2,\ldots,J \tag{2.21}$$

and

$$0 \leq x_h \leq \left(1-\frac{1}{N_h}\right) \quad , \quad h=1,2,\ldots,L \tag{2.22}$$

where v_j is the upper confidence bound to V_j.

They studied the existence and the uniqueness of the solution to this allocation problem and then provided an analytical solution.

Omule (1985) expressed this problem as a multistage decision process and optimized the allocation using dynamic programming techniques.

Other approaches have also been developed by Alemayehu and Sudasivan (1987). One approach they suggested was to formulate the problem using the L_1 - norm principle as follows:

Minimize

$$\sum_{h=1}^{L}\sum_{j=1}^{J} | d_{hj}| \qquad (2.23)$$

Subject to

$$\sum_{h=1}^{L} d_{h_j}=0, \qquad j=1,2,\ldots,J \qquad (2.24)$$

where $d_{hj} = n_{hj} - n_h$ and d_{hj} unrestricted in sign (2.25)

n_{hj} are optimum allocation values for the j^{th} variate in the h^{th} stratum.

The solution was obtained by using the simplex method of linear programming. Their other approach is one in which the solution of the problem was formulated as one in quadratic programming in the following manner:

Minimize

$$\sum_{h=1}^{L}\sum_{j=1}^{J} (n_{hj}-n_h)^2 \qquad (2.26)$$

Subject to

$$\sum_{h=1}^{L} n_h=n \qquad (2.27)$$

and

$$n_h > 0 \quad ; \quad h = 1, 2, ..., L \tag{2.28}$$

and

$$\sum_{h=1}^{L} c_h n_h = C - c_0 \tag{2.29}$$

where C is the total cost of the survey; c_o is the overhead cost; and c_h is the cost per unit in stratum h.

This non-linear programming problem was reduced, equivalently, to the following:

Maximize

$$k_0 + \sum_{h=1}^{L} k_h n_h - J \sum_{h=1}^{L} n_h^2 \tag{2.30}$$

Subject to

$$\sum_{h=1}^{L} n_h = n \tag{2.31}$$

and $\quad n_h > 0, \quad h = 1, 2, ..., L \quad$ and $\quad$ (2.32)

$$\sum_{h=1}^{L} c_h n_h = C - c_0 \tag{2.33}$$

where

$$k_0=\sum_{h=1}^{L}\sum_{j=1}^{J} n_{h_j^2}$$

and

$$k_h=2\sum_{j=1}^{J} n_{h_j}$$

Beale's algorithm was used to solve this quaratic programming problem.

The techniques compared in this dissertation are the optimum, compromise, proportional and Chatterjee based on individual Neyman allocations. Since the stratum variances were not available, the pilot survey results were used to estimate these variances.

2.3.2 Details of the methods applied

(i) The first method proposed to go about the problem encountered when the variables of interest are greater than one is to obtain the optimum allocation for each and then to opt for the average of the different optimum values (Cochran (1977)).

Thus,

$$n_h = \frac{\sum_{j=1}^{J} n_{jh}}{J} \qquad (2.34)$$

Where n_{jh} is the optimum sample size obtained for stratum h and variable j using the formula given above in (2.1);

(ii) The other alternative is to take the stratum sample sizes using proportional allocation, i.e. considering their relative weights in the population alone.

Thus,

$$n_h = \frac{N_h}{N} n \qquad (2.35)$$

or

$$n_h = W_h n \qquad (2.36)$$

(iii) The other alternative one can apply is the one developed by Chatterjee (1967). Here the n_h's are chosen in such a way as to minimize the average of the proportional increases in variance resulting from deviations from the optimum allocation values over all the variables. The proportional increase in variance due to the above is given by the following:

$$\frac{V(\bar{y}_{st}) - V_{\min}(\bar{y}_{st})}{V_{\min}(\bar{y}_{st})} = \frac{1}{n}\sum \frac{(\hat{n}_h - n'_h)^2}{\hat{n}_h} \qquad (2.37)$$

where

$\hat{n}_h$ is the actual allocatin in stratum h; and

n'_h is the optimum sampling in stratum h.

Thus, one chooses the n_h in such a way that the following holds:

$$n_h = n\sqrt{\sum_j n_{j_h}^2} \Big/ \sum_h \sqrt{\sum_j n_{j_h}^2} \qquad (2.38)$$

j=1,2,...,J

h=1,2,...,L

2.4 Nutritional assessment techniques

Contrary to the over nutrition problems found in the developed world the problems of the developing countries are deficiencies in the required nutrition values. According to FAO, malnutrition is defined as "a pathological state resulting from a relative or absolute defficiency or an excess in diet of one or more essential nutrients".

The nutritional situation of a community can be evaluated by adopting one of the following approaches:

(i) Dietary approach

This is an approach where the following indicators have to be estimated, i.e., (a) food consumption; (b) the nutritional content of the food intake; and (c) the nutritional requirements of the individual.

(ii) Anthropometric and related approaches [9]

This is an approach where one evaluates the health and related conditions of the individual that reflect the imbalance between the nutritional intake and expenditure.

The most commonly applied anthropometric measures include: (a) the WFH (weight for height); (b) the HFA (height for age); and (c) the WFA (weight for age) indicators. These indicators are often applied to assess the state of nutritional status by comparing data obtained to the standards established.

The HFA indicator is the least affected by temporary food defficiency and therefore is the most reliable indicator of chronic dietary inadequacy in childhood. However, the problem encountered in using anthropometry in the developing countries is that age data required for the commonly used HFA and WFA indicators are usually inaccurate. Thus,

[9] These include clinical, biochemical, mortality and other demographic parameters.

age misreporting make these indicators handicapped in such countries. Other anthropometric indicators include the measures of the circumference of the arm as well as the measure of the circumference of the head compared with standards developed by the WHO. But these will not be considered in this paper.

Protein-energy malnutrition (PEM) is a problem faced by many developing countries, even in normal times (i.e. when they have good harvests). It usually affects children between the age of 6 and 60 months. As stated earlier, body measurements are used to detect malnutrition. A chronically malnourished child will be stunted (i.e. will be short for his/her age). And an acute malnutrition may result in wasting (i.e. loss of muscle and fat implying the state of being thinner without effect on the health). Both stunting and wasting result in low WFA.

Intervention (national relief)

Four ways in which food relief may be organized in requiring situations include:

(i) general food distribution (i.e. dry food rations);

(ii) mass feeding (cooked meals);

(iii) supplementary feeding of vulnerable groups; and

(iv) intensive feeding of PEM cases.

2.5 Errors in Surveys

In general, both sampling and non-sampling errors occur in any sample survey exercise. The total error in a survey based on sample size n, consists of the square root of variable error plus the square of the bias of the estimate.

Hence, the total error would be given by the following:

$$\sqrt{V(t)+B^2(t)} \qquad (2.39)$$

where t is the estimator of the population parameters and V(t) is the sampling variance of t and B (t) is the bias of the estimator.

Non-sampling errors may be broadly classified as follows:

(i) Response errors;

(ii) Non-Response errors;

(iii) Tabulations and keying errors.

These errors may arise at the principal stages of the sample survey. Sometimes the non-sampling error component might be so large that the survey results are made unacceptable. It is wise to note the different types of error that may arise in surveys, to identify the various sources of such errors and to control these errors for an acceptable estimate of the population parameters.

CHAPTER III

DATA COLLECTION AND NON-SAMPLING ERRORS

3.1 General Background Information

The agro-ecological peculiarities of the area studied were used to stratify the poulation. This was applied because it was believed and there is ample evidence attests that the production patterns and other characteristics of the rural population entertain certain similarities within the different agro-ecological zones which are due to the environment encompasing the areas. These zones also exhibit heterogeneity between themselves. Thus the number of strata were made to be three accordingly and these were the Dega; Woyna Dega and Kolla agro-ecological zones (Kolla is a semi-arid type of climate and here refers to an altitude of 1 360 meters; Woyna Dega is a warm and mild type of climate and here refers to an altitude of 1 600 meters; and Dega is a temperate and chilly type of climate and here refers to an altitude of 2 100 meters).

The population studied is the aggregate of rural households [10] in the five PA's [11] comprising a community in the Damota district of the North Omo Administrative region.

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[10] The following definition has been used: "A household is considered to be an agricultural household when at least one member of the household is operating a holding or when the household head, reference person or main income earner is economically active mainly in agriculture." This definition covers two types of households those whose members operate a holding (farming households) and those whose haed (or main income earner) is economically active in agriculture although he does not operate a holding (non-farming agricultural households).

[11] The five PA's studied were Wachiga Isho, Serie Isho from the Kolla agro-ecological zone, Tome Gerera and Mante Gerera from the Woyna Dega agro-ecological Zone and Kokate from the Dega agro- ecological zone. The total number of households in each PA was 589, 668, 702, 643 and 610 respectively.

(the area map of the study site is shown as Annex I)

The Damota district was chosen as the study site following extensive consultations with the responsible authorities in the Relief and Rehabilitation Commission (RRC), the Ministry of Agriculture as well as the FAO National Office for Ethiopia. [12]

The following important indicators about Damota district were obtained from unpublished papers within the Ministry of Agriculture's Representative Office. The total population as at end 1989 was estimated to be 281,993 and the number of households were registered at the level of 37,917. The land area of the district is 179,000 hectares. The land use situation was also identified to be as follows: 70 per cent was used for agricultural production; 13 per cent for cattle grazing; 9 per cent was covered by forests and 8 per cent was used for other purposes. The district entertains the three agro-ecological zones and their share is as follows: 15 per ent Dega; 59 per cent Woyna Dega and 26 per cent Kolla. The distribution of the population by agro-ecological zones was assessed to be 7 per cent in the Dega area; 64 per cent in the Woyna Dega and 29 per cent in the Kolla areas. The main crops cultivated include maize; teff; kidney beans ("adenguarre"); wheat and barley in the order of their importance. [13] The livestock situation as at end 1989 of the Damota district

[12] It is worth noting that prior to undertaking the Damota district survey, a pilot survey was undertaken in North Shoa Administrative region in Sellale district with the intention of making Sellale the study area but was abandoned due to unfavourable developments. This has forced us to incur additional cost, escalating the project cost.

[13] Other very important agricultural production is the area relates to sweet potatoes; cassava and "Goderrie".

is shown as as Annex II. The monthly as well as yearly rainfall data covering the years 1983-1989 for Damota's district capital, Wolayta Sodo, is shown as Annex III.

It was noted that some NGOs had ongoing projects both short-term and long-term at the time of the survey to help vulnerable groups in the district in their efforts for survival. These included the World Vision; the Catholic Relief Service as well as others. The FAO national office is also active in the area and one of its areas of support was identified to be furnishing of a revolving fund which is used by the PA's to help poor peasants to buy oxen (their draught animals) which would be paid back to allow others to benefit from the fund on a continuous basis.[14] Some sad incidents were observed at the district where poor peasants who failed to honour their debts taken for fertilizer procurement were imprisoned. They were not able to pay back their debts because of crop failure and continued deterioration of agricultural productivity in the area.

3.2 Questionnaire Design

After extensive reading and appropriate considerations relating to terms used in the questions to avoid vagueness; choice of easily answerable questions to avoid load on the respondents; and to allow fast recording on the part of the enumerators by introducing code numbers as well as data processing considerations a tabular questionnaire was developed and utilized. Following the Sellale pilot survey that was undertaken from 20 to 25 February 1990 which served as a testing exercise, the questionnaire was reviewed and appropriately

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[14] These information were obtained from the Ministry of Agriculture's Damota Office.

modified to take care of the observations of the enumerators and supervisors who had tested them in the field. Benefiting from the above, the questionnaires were directly applied in the Damota district without any problems. However, another pilot survey of 50 households was deemed necessary in Damota district to determine the stratum variances for sample allocation purposes.

3.3 Enumerator Identification and Briefing

Enumerators for both the pilot and final surveys were identified from the area itself. These were twelfth grade complete students. The selection of the enumerators in all the agro-ecological zones was done by using a uniform selection criteria, i.e. readable handwriting; ESLCE results as well as common sense and the recommendations from the PA offices and Ministry of Agriculture extension agents who were knowledgeable to the students who were considered. Then the selected enumerators were given a briefing on how to fill out the questionnaires, and in addition sample questionnaires were filled out in front of them to develop ease of understanding and simplify the field work. Questions raised by the enumerators were answered appropriately and discussions were made in great detail.

Supervision was done by the instructor, the author and others identified by their experience. In addition, three agricultural extension agents were hired for this purpose from the district.

3.4 Frame

As clearly pointed out by Cochran (1977), "Before selecting the sample, the population must be divided into parts that are called sampling units. These units must cover the whole of the population and they must not overlap, in the sense that every element in the population belongs to one and only one unit."

Thus in this case, the frame refers to the list of households in the identified five PA's. The information was not readily available and it took time and energy to prepare a comprehensive list on the spot using various files as sources, including membership fee registration files and other relevant documents. These lists for the different PA's were not up-to-date as was required. But in the absence of alternatives whatever was made available by the PA offices was used. The use of this information, however, did not affect negatively the results of the survey.

3.5 Pilot Survey

3.5.1 Determination of Sample Size

A pilot survey was undertaken which covered fifty households per stratum. This was done to obtain estimates of the stratum variances since the population values were not available. The results obtained were used in combination with a linear cost function to determine the sample size, n.

The data on production (Current year's and last year's), expenditure, food reserves and food purchases were collected in kilograms. But since there were different crops reported their values in kilograms were converted into a common denominator and their totals considered (ENI and SIDA (1968)).[15] Other data collected included acreage (current year's and last year's) and family size. These are few of the various variables that were considered vital for sample allocation purposes.

Method I

The budget approved for the survey by the various committees in the University was used as the total cost and, the unit costs in the diffrent strata were estimated using the expenditure that was made for the pilot survey is Sellale region as well as that available for the current pilot survey undertaken in the Damota district. The computations are shown in the following tables and the cost function used is the following:

$$C = c_o + \sum_{h=1}^{3} c_h n_h$$

$$=> 2177 = 549 + \Sigma c_h n_h$$

where Birr 2177 is total cost of survey (C) and Birr 549 is the overhead cost (c_o).

[15] The techniques developed by ENI and SIDA were utilized for the purpose in the study.

(i) Family size

Stratum [16]	N_h	s_h	$N_h s_h$	c_h	$\sqrt{C_h}$	$N_h s_h/\sqrt{C_h}$	$N_h s_h\sqrt{C_h}$
1	610	2.56	1564.65	2.50	1.58	989.66	2473.71
2	1257	2.86	3598.79	1.50	1.23	2937.79	4408.52
3	1345	2.75	3704.13	1.25	1.12	3313.18	4141.22
Total	3212					7240.63	11023.45

Using the above in the formula for n given in (2.3),

$$n = \frac{(1628)\ (7240.63)}{11023.45} = 1069.3$$

(ii) Current year's Acreage

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{C_h}$	$N_h s_h/\sqrt{C_h}$	$N_h s_h\sqrt{C_h}$
1	610	28.38	17309.36	2.50	1.58	10948.36	27366.10
2	1257	0.62	774.31	1.50	1.23	632.09	948.53
3	1345	0.58	781.45	1.25	1.12	698.97	873.66
Total	3212					12279.42	29186.29

$$n = \frac{(1628)\ (12279.42)}{29186.29} = 684.9$$

[16] Throughout the paper stratum 1 = Dega ; 2 = Kolla and 3 = Weyna Dega.

(iii) Last Year's Acreage

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{c_h}$	$N_h s_h/\sqrt{c_h}$	$N_h s_h\sqrt{c_h}$
1	610	28.37	17304.48	2.50	1.58	10945.28	27358.38
2	1257	0.63	793.17	1.50	1.23	647.48	971.63
3	1345	0.61	816.42	1.25	1.12	730.25	912.75
Total	3212					12323.04	29242.77

$$n = \frac{(1628)\ (12323.01)}{29242.77} = 686$$

(iv) Current Year's Production

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{c_h}$	$N_h s_h/\sqrt{c_h}$	$N_h s_h\sqrt{c_h}$
1	610	339.49	207089.51	2.50	1.58	13098.41	327408 .51
2	1257	370.22	465370.31	1.50	1.23	379894.13	570078 .63
3	1345	508.84	684391.15	1.25	1.12	612156.66	765149 .30
Total	3212					1123037.20	1662636.45

$$n = \frac{(1628)\ (1123037.20)}{1662636.45} = 1099.6$$

(v) Last Year's Production

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{c_h}$	$N_h s_h/\sqrt{c_h}$	$N_h s_h\sqrt{c_h}$
1	610	386.39	235697.29	2.50	1.58	149081.15	372637.42
2	1257	850.54	1069132.55	1.50	1.23	872761.27	1309687.38
3	1345	557.78	750216.79	1.25	1.12	671034.70	838742.37
Total	3212					1692877.12	2521067.17

$$n = \frac{(1628)\ (1692877.12)}{2521067.17} = 1093.2$$

(vi) Expenditure

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{c_h}$	$N_h s_h/\sqrt{c_h}$	$N_h s_h\sqrt{c_h}$
1	610	392.71	239552.49	2.50	1.58	151519.60	378732.49
2	1257	293.59	369045.14	1.50	1.23	301261.34	452080.30
3	1345	502.38	675703.79	1.25	1.12	604386.22	755436.84
Total	3212					1057167.16	1586249.63

$$n = \frac{(1628)\ (1057167.16)}{1586249.63} = 1085.0$$

(vii) Food Reserves

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{C_h}$	$N_h s_h/\sqrt{C_h}$	$N_h s_h\sqrt{C_h}$
1	610	138.04	84206.84	2.50	1.58	53261.76	133131.01
2	1257	44.35	55747.95	1.50	1.23	45508.53	68291.24
3	1345	97.74	131464.34	1.25	1.12	117588.85	146977.13
Total	3212					216359.14	348349.38

$$n = \frac{(1628)\ (216359.14)}{348399.38} = 1011.1$$

(viii) Food purchase

Stratum	N_h	s_h	$N_h s_h$	c_h	$\sqrt{C_h}$	$N_h s_h/\sqrt{C_h}$	$N_h s_h\sqrt{C_h}$
1	610	140.56	85739.77	2.50	1.58	54231.35	135554.58
2	1257	302.42	380136.41	1.50	1.23	310315.85	465667.72
3	1345	184.79	248541.21	1.25	1.12	222308.77	277869.07
Total	3212					586855.97	879091.37

$$n = \frac{(1628)\ (586855.97)}{879091.37} = 1086.8$$

Method II

The other method applied to determine the sample size, n, was the following. It assumed a similar per unit cost in all the strata. This was arrived at by taking the average of the cost estimates used in the above computations which was 1.75. Thus :

$$C = C_0 + cn$$

$$2177 = 549 + (1.75)\, n$$

$$\Longrightarrow 1.75n = 1628$$

$$n = 930$$

Then taking averages of all the values of n arrived at in both methods applied above n was taken to be 960.

3.5.2 Allocation of sample sizes to Strata

A. Optimum, compromise and proportional allocation

The individual optimum allocation values were obtained using the following information and compromise allocation values also obtained. The computations used are shown in the following tables:

(i) Standard deviations within strata

Stratum	$W_h=N_h/N$	S_h, Family size	S_h, Current year's acreage	S_h, Last year's acreage	S_h, Current year's production	S_h, Last year's production
1	0.19	2.57	28.38	28.37	339.49	386.39
2	0.39	2.86	0.62	0.63	370.22	850.54
3	0.42	2.75	0.58	0.61	508.84	557.78

(ii) Standard deviations within strata (Contd.)

Stratum	S_h, Expenditure	S_h, Reserves	S_h, Food Purchase
1	392.71	138.04	140.56
2	293.59	44.35	302.42
3	502.38	97.74	184.79

(iii) Allocation of Sample sizes within Strata

(n = 960)

Stratum	Proportional	Optimum for			
		Family size	Current year's acreage	Last year's acreage	Current year's production
1	183	170	881	879	147
2	375	389	39	40	329
3	402	401	40	41	484

(iv) Allocation of Sample sizes within Strata (Contd.)

(n = 960)

Stratum	Optimum for				Compromise*
	Last year's production	Expenditure	Reserves	Food Purchase	
1	110	179	298	115	170
2	499	276	197	511	367
3	351	505	465	334	423

* The compromise allocation is obtained as the average of the individual optima, but excludes optimum for current year's acreage and last year's acreage which had a completely different result as opposed to the others since they require more than 100 per cent sampling (see Cochran (1977), p. 104.

B. Chatterjee's Method of allocation

The method developed by Chatterjee was also applied for comparison purposes.

Computations for Chatterjee's Allocation

Stratum	Square of the Optimum (n^2_{jh})							
	Family size	Current Year's Production	Last year's Production	Expen- diture	Reserves	Food Purchases	$\Sigma n'^2_{jh}$	$\sqrt{\sum n^2_{jh}}$
1	28900	21609	12100	32041	88804	13225	196679	443.5
2	151321	108241	249001	76176	38809	261121	884669	940.6
3	160801	234256	123201	255025	216225	111556	1101064	1049.3
Total								2433.4

* The values for current year's acreage and last year's acreage have not been considered.

Using (2.38), we get:

$$n_1 = \frac{960 \times 443.5}{2433.4} = 175$$

$$n_2 = \frac{960 \times 940.6}{2433.4} = 371$$

$$n_3 = \frac{960 \times 1049.3}{2433.4} = 414$$

These stratum sample sizes are not very much different from that obtained using the compromise allocation technique.

C. Expected Variances of the Estimated Means

The expected variances of the estimated mean were obtained using the following formulae:

$$V_{opt} = (\Sigma W_h s_h)^2/n$$

$$V_{compromise} = \Sigma((W_h s_h)^2/n_h)$$

$$V_{proportional} = (\Sigma W_h s_h^2)/n$$

Expected Variances of the Estimated Means *

Type of allocation	Family size	Current year's production	Last year's production	Expenditure	Food Purchase
Optimum	0.0079	185.9	426.2	166.6	51.5
Compromise	0.0079	189.0	462.2	173.4	56.0
Proportional	0.0080	191.6	460.0	175.8	56.1

* The values for reserves were not in conformity to expected outcomes and therefore are not shown in this table.

Since, by and large, the expected variances of the the estimated means arrived at using the compromise allocation technique were lower, this method was adopted and the sample elements were selected accordingly.

3.6 Final Survey

The selection of the sample elements was done using random numbers generated by a computer programme in the three strata.[17]

The Nutritional situation of the community studied was assessed by means of anthropometry. Weight, height, birth date and sex for all children aged 12 to 60 months which happened to be members of the identified households were recorded. Measurements were taken by enumerators of the final survey while visiting the households in the course of the interviews.

Weights were measured in kilogrammes with Salter scales obtained from the ENI. The children were placed in a harness of plastic shorts with hangers which were hooked to the scale. Heights were measured with measuring boards which had a fixed head-rest at the lying position and a moveable foot-rest and a fixed tape measure. Each child was placed on the board in supine position with head against the head-rest. Their birth-dates were also

[17] Random numbers generated by using SPSS-X Release 2.2 were used to identify elements to be included in the sample.

recorded to the best possible accuracy.

The data obtained for each child will be compared with the WHO standards. The following are the three "indices" that will be computed and results obtained discussed in Chapter IV:

(i) Weight-for-height (WFH) converts the weights of the child into a percentage of the standard weight expected for the height of the child;

(ii) Height for age (HFA) expresses the height of the child as a percentage of the standard height expected for the age of the child;

(iii) Weight-for-age (WFA) expresses the weight of the child as a percentage of the standard weight for the age of the child.

The above described "indices" reflect different aspects of nutritional status. It is assumed that when a child is malnourished the weight gain slows down and may even deteriorate, theus a low weight-for-height.

3.7 Field Work

The pilot surveys as well as the final survey were behind schedule due to, inter alia, the following reasons:

(i) the time taken by the various committees in the University regarding approval of the project proposals;

(ii) funding problems encountered both from the University as well as outside funding agencies;

(iii) the unfavourable situation in the country.

The survey activities in the Damota district extended from 1 to 7 May 1990. Due to the fact that schedules were not met, many enumerators were hired at once to buy the lost time. A total number of forty-eight enumerators and six supervisors were mobilized for the survey work.

Following the pilot survey which provided estimates of the stratum variances the stratum sample sizes were determined automatically as discussed earlier.

3.8 Problems encountered

The following were the main problems encountered in the execution of the surveys:

(i) the project proposal, although was distributed to potential donors ahead of time and although they showed considerable interest in the study, the fund was not secured on time and this has been one of the major problems encountered, since the School of Graduate Studies didn't have provisions to avail even the humble amount it approved.

(ii) Age data reporting in the case of children under the age of five for the nutritional assessment exercise had the usual problems of inaccurancy;

(iii) The lack of required cooperation from responsibles in the various government offices.

(iv) The absence due to different social commitments (funerals, etc.) of inhabitants of households in the sample. This forced the enumerators to go to one household more than once. But although callbacks were necessary all the elements in the sample were interviewed.

3.9 Non-sampling Errors in the Survey

In this particular case, a pilot survey was conducted and the questionnaire improved prior to application to the final survey. This is believed to have reduced some of the response errors that could have been encountered. Further, enumerators and supervisors were given adequate orientation and training. Moreover, a relatively large number of enumerators were assigned each dealing with not more than 20 respondents. The educational background of the enumerators was high school complete and they were fluent in the local language. All these steps adhered to in the organization of the survey are hoped to reduce the errors in the survey. In spite of these efforts, however, there are bound to occur certain enumerators effects in the survey and as a result there could be some amount of response bias. Similarly, because of underreporting tendencies due to various reasons, regarding most of the variables, the respondents may be the sources of some response bias.

A further problem encountered as mentioned earlier was the lack of an up-to-date sampling frame. This was constructed mostly from lists of households prepared for other purposes sometime ago. As a result, there may be omissions of certain households or some that do not exist may have been included in the frame. Such faulty frames may give rise to non-response errors in the survey.

The problems encountered relating to measurement are also pertinent in the uses of the results of the survey. Since in the developing countries, the systems and cultures of registering what is produced and consumed, etc. does not exist respondants to questionnaires of surveys give answers which may have inherent biases in them. The other related problem is that they may think in terms of traditional units of measurement used in the area and in the process of converting these data to the required units undesired errors can be introduced into the data which make the use of such data very limited. In spite of these defficiencies however, every effort was made to get accurate estimates of the population parameters within the budget and time constraints of the survey.

CHAPTER IV

ANALYSIS OF SURVEY RESULTS

4.1 Introduction

The main aspects of sample size determination and stratification and the related problems of sample allocation have been dealt with in the previous chapter. Thus, this part of the paper analyzes the following:

(i) Estimates of the population means of the variables studied as well as their respective variances and the application of the results to a food supply system;

(ii) Review of the nutritional assessemnt results.

4.2 Estimates of the Population Values of the Variables Studied

The estimates of the population means of the variables under study are obtained as follows:

The sample means for the different variables j, (j = 1,2,...,J) are obtained as follows:

$$\bar{y}_h^j = \frac{\sum_{i=1}^{n_h} y_{hi}^j}{n_h}$$

where j refers to the different variables studied (j = 1, 2, ... J); h refers to the strata (h = 1, 2, ..., L) and i refers tothe individual observations (i = 1, ..., n_h).

Then, the estimates of population means per unit for each variable are obtained using the following formula:

$$\bar{y}_{st}^j = \sum_{n=1}^{L} W_h \bar{y}_h^j$$

Means of Different Variables (y^j_h)

Variables								
L	Family size	Current Year's acreage (ha)	Last Yr's acreage (ha)	Current Year's production (Kcal)	Last Yr's production (Kcal)	Expenditure (kcal)	Food Reserves (Kcal)	Purchases (Kcal)
1	6.141	2.305	2.296	700.451	863.520	333.146	62.860	308.654
2	6.278	1.270	1.344	745.549	1014.664	453.235	59.520	566.646
3	6.673	1.286	4.188	817.235	886.158	516.300	47.942	250.260

The following are obtained from the data on the above tables:

(i) $\bar{y}_{st}$ (family size)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	6.141	1.167
2	0.391	6.278	2.455
3	0.419	6.673	2.796
Total			6.418

Therefore, $\bar{y}_{st}$ (family size) = 6.418

(ii) $\bar{y}_{st}$ (Current Year's Acreage)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	2.305	0.438
2	0.391	1.270	0.497
3	0.419	1.286	0.539
Total			1.474

Therefore, $\bar{y}_{st}$ (Current Year's Acreage) = 1.474

(iii) $\bar{y}_{st}$ (last year's Acreage)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	2.296	0.436
2	0.391	1.344	0.526
3	0.419	4.188	1.755
Total			2.717

Therefore, $\bar{y}_{st}$ (last year's acreage) = 2.717

(iv) $\bar{y}_{st}$ (Current year's production)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	700.451	133.085
2	0.391	745.549	291.510
3	0.419	817.235	342.423
Total			767.016

Therefore, $\bar{y}_{st}$ (Current year's production) = 767.016

(v) $\bar{y}_{st}$ (last year's production)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	863.520	164.069
2	0.391	1014.664	396.734
3	0.419	886.158	371.300
Total			932.103

Therefore, $\bar{y}_{st}$ (Previous year's production) = 932.103

(vi) $\bar{y}_{st}$ (Expenditure)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	333.146	63.298
2	0.391	453.235	177.215
3	0.419	516.300	216.330
Total			456.843

Therefore, $\bar{y}_{st}$ (Expenditures = 456.843

(vii) $\bar{y}_{st}$ (food reserves)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	62.860	11.943
2	0.391	59.520	23.272
3	0.419	47.942	20.088
Total			55.303

Therefore $\bar{y}_{st}$ (food reserves) = 55.303

(viii) $\bar{y}_{st}$ (purchases)

Stratum	W_h	$\bar{y}_h$	$W_h\bar{y}_h$
1	0.190	308.654	58.644
2	0.391	566.646	221.559
3	0.419	250.261	104.859
Total			385.062

Therefore, $\bar{y}_{st}$ (purchases) = 385.062

Variances of the Stratified Means

The variances of the stratified means were computed by using the following formula:

$$V(\bar{y}_{st}) = \frac{1}{N^2}\sum_{h=1}^{L}\frac{N_h(N_h-n_h)}{n_h}s_h^2$$

(i) Family size

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	6.14	6.75	1578.82	10657.04
2	1257	367	6.28	5.71	3048.31	17405.85
3	1345	423	6.67	7.93	2931.65	23247.98
Total	3212	960				51310.87

$$V(\bar{y}_{st}) = \frac{51310.87}{10316944} = 0.00497$$

(ii) Current Year's Acreage

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	2.305	237.73	1578.82	375332.98
2	1257	367	1.270	0.70	3048.31	2133.82
3	1345	423	1.286	0.82	2931.65	2403.95
Total	3212	960				379870.65

$$V(\bar{y}_{st}) = \frac{379870.65}{10316944} = 0.037$$

(iii) Last Year's Acreage

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	2.30	237.74	1578.82	75348.67
2	1257	367	1.34	0.34	3048.31	2164.30
3	1345	423	4.19	1269.43	2931.65	3721524.46
Total	3212	960				4099037.43

$$V(\bar{y}_{st}) = \frac{4099037.43}{10316944} = 0.40$$

(iv) Current Year's Production

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	700.45	378859.41	1578.82	598150813.7
2	1257	367	745.55	362200.68	3048.31	1104099955.0
3	1345	423	817.24	467990.78	2931.65	1371985170.0
Total	3212	960				3074235939.7

$$V(\bar{y}_{st}) = \frac{3074235939.7}{10316944} = 298.0$$

(v) Last Year's Production

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	863.52	82334.72	1578.82	129991702.6
2	1257	367	1014.66	727073.96	3048.31	2216346823.0
3	1345	423	886.16	738174.43	2931.65	2164069068.0
Total	3212	960				4510407594.6

$$V(\bar{y}_{st}) = \frac{4510407594.6}{10316944} = 437.2$$

(vi) Expenditure

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	333.1	133771.95	1578.82	211201830.1
2	1257	367	453.24	162342.32	3048.31	494869717.5
3	1345	423	516.30	216014.83	2931.65	633279876.4
Total	3212	960				1339351424.0

$$V(\bar{y}_{st}) = \frac{1339351424.0}{10316944} = 129.8$$

(vii) Food Reserves

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	62.86	28511.45	1578.82	45014447.5
2	1257	367	59.52	19936.76	3048.31	60773424.9
3	1345	423	47.94	5284.47	2931.65	15492216.3
Total	3212	960				121280088.7

$$V(\bar{y}_{st}) = \frac{121280088.7}{10316944} = 11.8$$

(viii) Purchases

Stratum	N_h	n_h	$\bar{y}_h$	s_h^2	$\frac{N_h(N_h-n_h)}{n_h}$	$\frac{N_h(N_h-n_h)}{n_h}s_h^2$
1	610	170	308.65	226974.63	1578.82	358352085.3
2	1257	367	566.65	203805.90	3048.31	621263837.4
3	1345	423	250.26	87268.49	2931.65	255840668.7
Total	3212	960				1235456591.4

$$V(\bar{y}_{st}) = \frac{1235456591.4}{10316944} = 0.0084$$

The following test of hypothesis was applied to data on production to establish if there is a difference between the stratified means especially the current years production and last year's production:

Thus:

$$H_o: \mu_1 = \mu_2$$

$$H_1: \mu_1 < \mu_2$$

where μ_1 = current year's average production

μ_2 = last year's average production

and $\alpha = 0.05$

Then

$$t = \frac{\bar{y}_1 - \bar{y}_2}{\hat{\sigma}} \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

Where $\bar{y}_1$ is the stratified mean of the current year's production and $\bar{y}_2$ is the stratified mean of last year's production.

Where

$$\hat{\sigma}^2 = \frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}$$

Where

n_1 = is sample size for current year's production

n_2 = is sample size for last year's production

s_1^2 = is the stratified variance of current year's production; and

s_2^2 = is the stratified variance of last year's production.

Thus t has a t distribution with $n_1 + n_2 - 2$ degrees of freedom.

In this particular case:

$n_1 = 960$; $n_2 = 960.$

$\bar{y}_1 = 767.016$; $\bar{y}_2 = 932.103$

$S_1^2 = 297.9$; $S_2^2 = 437.2$

This implies that

$$\hat{\sigma}^2 = \frac{285984+419712}{1918} = 367.93$$

and

$$\sqrt{\frac{n_1 n_2}{n_1+n_2}} = 21.9$$

Therefore t calculated will be

$$t = \frac{(165.087)(21.9)}{\sqrt{19.2}} = 188.3$$

The critical value of t from table for 1918 degrees of freedom was found out to be 1.645. Thus we reject the null hypothesis. This indicates that current year's production is less than the previous year's production.

4.3 Nutritional Status Appraisal

A total of 460 children were investigated in the survey. And these were 74 from the Dega agro-ecological zone; 156 from the Woyna-dega agro-ecological zone; and 230 from the Kolla agro-ecological zone.

The results of the nutritional situation assessment of the community studied are shown in the following summary tables. The detailed computations are attached as Annex IV. For the purpose of the study, a cut-off point for the WFH of 80 per cent is thought to be appropriate. Since those below 70 per cent (WFH) are very few in percentage.

(a) WFH (per cent)

Stratum	Below 90 per cent			Below 80 per cent			Below 70 per cent		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1	36.4	29.2	33.3	18.2	12.5	15.8	15.2	4.2	10.5
2	19.6	25.5	22.6	3.3	6.1	4.7	1.1	1.0	1.1
3	27.5	33.3	30.7	1.4	3.7	2.7	0.0	1.2	0.7

(b) HFA (per cent)

Stratum	Below 90 per cent			Below 80 per cent			Below 70 per cent		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1	28.6	34.4	31.1	4.8	15.6	9.5	4.8	3.1	4.1
2	42.0	35.6	38.7	18.9	18.6	18.7	11.6	7.6	9.6
3	44.4	35.7	39.7	6.9	7.1	7.1	1.4	0.0	0.6

(c) WFA (per cent)

Stratum	Below 90 per cent			Below 80 per cent			Below 70 per cent		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1	85.7	81.3	83.8	33.3	56.3	43.2	19.0	31.2	24.3
2	59.8	65.3	62.6	35.7	35.6	35.6	14.3	11.0	12.6
3	79.2	73.8	76.3	52.7	51.2	51.9	19.4	16.7	17.9

Taking the cut-off point for acute malnutrition using the WFH index as 80 per cent then the total population of the children investigated which was below the cut-off by agro-ecological zones point was as follows:

WFH

Stratum 1	Below 80 per cent		
	Male	Female	Total
1	33.4	16.7	26.3
2	4.4	7.1	5.8
3	1.4	4.9	3.4

The above shows that the acute malnutrition incidence in stratum 1 is high as compared to the other strata. Stratum 3 has the lowest.

Using the same cut-off point for HFA the following are obtained:

HFA

Stratum 2	Below 80 per cent		
	Male	Female	Total
1	9.6	18.7	13.6
2	30.5	26.2	28.3
3	8.3	7.1	7.7

The difference exhibited between the two indicators was expected. This is because the age data which are used for the purpose of obtaining the indicators are themselves misreported. According to the results obtained for HFA Stratum 2 has serious malnutrition problems followed by Stratum 1.

In the case of WFA indicators one can use the results in the table above since a cut-off point of 70 per cent will serve the purpose of investigation. Thus, stratum one shows an overall malnutrition rate of 24 per cent followed by stratum 3 where this is only 18 per cent; and stratum 2 with 13 per cent.

Although the results using different indicators gave different trends, the results indicate there is severe malnutrition in the area.

Although the results have not been included in this paper, a multiple regression fit was investigated by first obtaining scatter plots of the different nutritional status indicators (WFH, HFA and WFA) and the other variables obtained from the survey for the respective agro-ecological zones. The plot of the residues was also studied. This was done in an attempt to investigate the relationship of the nutritional status of the community which was regarded to be dependent on the other variables collected by the survey (i.e., production, family size, acreage, expenditure, food reserves and food purchase, taking them as the independent variables). The plots obtained indicated the absence of linear relationships and the multiple regression fits gave very poor values of R^2, the coefficient of determination values. The matrix of the correlation coefficients first investigated indicated in the same way that there was no linear relationship. Therefore, the attempt of introducing this method of investigation to determine which one of the variables collected highly determined the nutritional status of the community was abandoned.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The main objective of the study was to compare various methods developed to go about the problem of optimum allocation encountered when the study variables of interest are greater than one. This problem is encountered because what is best for one variable may not necessarily be best for the other. Thus, the results in the preceding chapters have established that the compromised allocation techniques can be applied in such cases. The other methods which involve the use of various non-linear programming techniques have not been applied to the data of this survey but are believed to give good results. These methods have been appropriately reviewed in Chapter II. The application of these complex techniques has recently been facilitated by special softwares prepared for particular use in this area.

Since the required variances of the population under consideration were not available, there was need to estimate these using results of a pilot survey. The use of these estimates by itself is believed to introduce another problem and this effect on the estimates is an independent area for future studies. In cases where previous studies relating to the study population or other previous studies about a similar population exist, the variance values could be taken as estimates of the variances. In this particular case, since such data were not available, the pilot survey was a necessity. For other surveys, where past studies furnishing variance values could be obtained, their use would mean lowering the cost of the survey since a pilot survey need not be undertaken.

In respect to going about the problem of sample allocation encountered due to various study variables, the study has shown that methods that are not very complex can be applied without any problem and these could save a good amount of money and at the same time will also help increase efficiency of the estimates of the population parameters required. The procedures required in this regard have been discussed in detail in the previous chapters of the study. Thus, it is recommended that such pilot surveys be undertaken in the absence of previous surveys to estimate the required stratum variances and the techniques reviewed be adhered to in such instances.

The arbitrary decision used in many surveys of taking say ten per cent of the population as the sample used in many undertakings does not seem to be scientific. Since the procedures of sample size determination adopted in the study are simple and very easy to apply, these procedures are strongly recommended for future surveys with a view to minimizing the variances of the estimates.

Nutritional status assessment should be carried out to identify vulnerable groups by different categories including sex, age group, etc. It is believed that this will facilitate the identification of the needy as well as the type of intervention required including nutritional relief measures. The results of the study strongly recommend the use of the methods that were applied in the country with a view to making the assessments meaningful and the interventions appropriate.

The EWS is a nation wide system and we believe that the disaster area assessment techniques of this study could be used to supplement the system. Thus an intensive methodological adoption by the EWS is recommended.

The findings of the survey indicate that there is malnutrition in the area studied. We, therefore recommend that an immediate intervention programme be carried out by the concerned authorities. The interventions include both short term and long term measures. The short term measures include supplementary feeding programmes, whereas the long term ones include development oriented and multisector packages.

After such interventions, further studies should be conducted with a view to comparing the impacts of the intervention with the results established in this paper.

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Annex I

Annex II

Livestock of Damota District

Type	Number
Cattle	94 990
Goats	15 383
Sheep	9 264
Mules	1 175
Horses	1 157
Asses	4 234
Poultry	63 549

Source: Ministry of Agriculture, Damota Office, Unpublished paper.

Annex III

Rainfall Data for Wolayta Sodo

(Rainfall in mm and No. of Rainy Days)

Month	1983	1984	1985	1986	1987	1988	1989
Jan.	23.0	0	19.7	5.7	10.2	78.8	
Feb.	23.8	0	30.5	11.4	4.8	50.2	
March	43.8	40.7	48.6	44.0	106.8	37.4	81.9
April	173.1	36.5	24.5	82.2	141.1	171.7	100.8
May	135.1	190.6	118.0	195.1	370.0	87.3	135.3
June	11.8	184.8	123.4	-	112.8	68.9	77.9
July	67.8	60.7	96.6	-	25.9	279.4	102.8
Aug.	267.3	174.0	35.9	-	154.4	212.2	151.4
Sept.	16.2	198.5	31.9	-	114.4	167.7	112.1
Oct.	62.9	2.5	7.7	-	125.6	147.2	85.2
Nov.	63.4	23.2	40.2	35.3	21.9	-	41.0
Dec.	-	36.5	30.4	31.6	-	-	196.6
Total Rain-fall in mm	888.2	948.0	607.4	405.3	1217	1227.9	1214
Rainy days	69	119	96	50	127	149	169

Source: Ministry of Agriculture, Damota Office, Unpublished papers.

Annex IV
Stratum 1 (Dega)
Children under 5 years of age

Age months	Sex	Weight (kg)	Height (cm)	Indices		
				WFH	HFA	WFA
36		12	88	97	92	83
36	M	11.2	86	93	90	77
36	M	12	86	100	90	83
60	M	16	90	125	83	87
48	M	14	90	109	87	85
13	M	12	28	...	37	118
24	M	10	93	74	107	81
48	M	13.5	92	102	89	85
36	M	12	86	100	90	83
36	M	12	81	109	84	83
60	M	15.5	96	109	88	84
48	M	14	94	102	91	85
60	M	13	99	86	91	71
36	F	11.3	88	91	92	78
12	M	7.5	62	...	83	76
60	F	16	160	...	148	87
24	M	12.5	91	96	104	101
24	M	12.5	96	88	110	101
12	F	6.5	64	...	86	66
48	F	12	131.5	...	127	73
36	M	13	99	86	103	90
48	M	14	94	102	91	85
24	F	12.5	91	96	104	101
12	F	12	84	104	112	121
36	F	11.1	88	90	92	77
36	F	12	86	100	90	83
36	F	12	86	100	90	83
36	M	11.3	90	88	94	78
15	M	7.8	68	...	87	74
48	F	12.2	96	86	93	74
24	F	11	86	92	99	89
31	M	11.2	83	98	90	82
36	F	11.3	85	97	89	78
60	F	15	100	97	92	82
36	M	11	94	80	98	76
48	F	13.6	48	...	46	82
60	F	15.5	104	94	95	84
60	F	13.4	86	112	79	73
24	F	9.6	75	99	86	77
48	F	9.1	123	...	119	55
36	M	7.5	86	62.5	90	52
60	M	8.2	120	...	110	45
48	F	9.5	123	...	119	58
36	M	16	125	...	130	110
12	F	8.5	89	67	119	86
36	M	13	88	105	92	90
24	M	8.1	102	51	117	65
48	M	9.1	123	...	119	55
24	M	8.3	105	49	121	67
16		6.5	76	66	96	60

Age months	Sex	Weight (kg)	Height (kg)	Indices		
				WFH	HFA	WFA
48	F	9.1	130	...	126	55
12	M	6.1	76	62	102	62
36	F	8.2	85	70	89	57
36	F	11.5	81	105	84	79
36	F	7	66	...	69	48
12	F	6.5	64	...	86	66
36	M	13	96	92	100	90
48	M	14	94	102	91	85
60	M	15	110	82	101	82
60	M	15.5	100	101	92	84
36	M	12.5	84	109	88	86
36	F	9	75	93	78	62
36	M	12.4	87	102	91	86
48	F	7.8	77	77	75	47
60	M	27.5	98	186	90	149
48	M	15.5	92	117	89	94
24	M	10	80	93	92	81
12	F	8	68	...	91	81
24	F	8	73	87	84	65
36	F	14.7	98	99	102	101
12	M	8.5	68	...	91	86
24	M	10.5	86	88	99	85
12	M	8.6	75	89	100	87
36	F	9	73	98	76	62

Stratum 2 (Kolla)

Children under 5 years of Age

Age months	Sex	Weight (kg)	Height (kg)	Indices		
				WFH	HFA	WFA
48	F	13	85	111	82	79
42	F	18	73	96	73	116
12	M	12	46	...	62	121
12	M	1.1	41	...	55	112
48	M	15	49	...	47	91
48	M	14	28	...	27	85
60	M	17	83	149	76	92
60	M	17	98	115	90	92
36	F	14	69	...	72	97
24	F	8.4	89	67	102	68
36	M	16	43	...	45	110
48	F	10	67	...	65	61
24	M	8	41	...	47	65
48	F	8	61	...	59	48
48	M	10.4	45	...	44	63
12	F	15	58	...	78	151
36	F	11	44	...	46	76
48	F	12	54	...	52	73
48	F	14	108	79	105	85
12	M	5.5	49	...	66	56
48	M	14.4	110	78	106	87
48	F	16	83	140	80	97
12	F	9	61	...	82	91
24	M	8.4	49	...	56	68
48	F	15.1	102	94	99	92
24	M	12.5	86	104	99	101
36	F	10.7	84	93	88	74
36	F	15.0	106	88	110	103
36	M	15.5	111	...	116	107
24	F	12.4	93	92	107	100
48	M	15.8	109	88	106	96
12	M	11.6	86	97	115	117
60	F	20.5	119	...	109	111
48	M	19.5	111	...	107	118
36	F	13.8	96	97	100	95
24	M	12.3	82.5	109	95	99
24	M	11.4	86	95	99	92
48	F	14.4	104	87	101	87
36	F	9.5	75	98	78	66
48	M	12.3	89	98	86	75
12	M	9.1	76	92	102	92
60	M	12.2	87	101	80	66
36	M	9.8	82	88	85	68
36	M	11.4	82	102	85	79
48	M	19	110	103	106	115
36	F	13.3	75	137	78	92
48	M	13.6	97	94	94	82
36	M	12.7	88	102	92	88
60	M	16.5	108	93	99	90
36	M	12.8	92	97	96	88
24	F	10.8	83	95	95	87

Age months	Sex	Weight (kg)	Height (cm)	Indices		
				WFH	HFA	WFA
60	F	15	106	88	97	82
12	F	9	71	103	95	91
48	M	12.3	90	96	87	75
48	M	12	94	88	91	73
12	F	8.9	66	...	88	90
36	F	14.8	102	93	106	102
12	M	11.9	85	102	114	120
48	F	14.3	99	95	96	87
36	M	13.0	90.2	102	94	90
60	F	15.5	105	92	96	84
36	M	11.5	87.3	94	91	79
60	F	14	99	93	91	76
36	F	10.7	84	93	88	74
24	F	14.6	104	88	119	118
12	F	9	75	93	100	91
36	F	13	99	86	103	90
24	F	10	79	94	91	81
60	M	17.5	106	102	97	95
60	F	19	110	103	101	103
60	M	13.3	99	88	91	72
36	M	12	91	92	95	83
24	F	10	89	79	102	81
60	F	12.3	98	83	90	67
24	F	11.0	92	83	106	89
36	M	11	81	100	84	76
24	M	11	80	102	92	89
48	F	16	89	130	86	97
24	F	15	88	121	101	121
12	F	8	55	...	74	81
48	M	14	92	106	89	85
60	F	14	100	91	92	76
36	M	11	76	111	79	76
60	F	18	108	102	99	98
36	M	12	84	104	88	83
60	F	15	96	106	88	82
36	F	14	82	125	85	97
18	M	9	70	106	86	80
48	M	14.3	95	102	92	87
60	F	14.3	101	91	93	78
48	F	12	94	88	91	73
24	F	8.8	73	96	84	71
24	F	11.3	78	109	90	91
48	M	13.7	87	113	84	83
24	F	8.3	66	...	76	67
60	F	13.5	102	84	94	73
36	M	10.8	85	92	89	74
36	F	13.5	88	109	92	93
36	M	11.2	83	98	86	77
24	M	8.0	72	89	83	65
60	M	14.5	102	91	94	79
60	M	15.4	107	89	98	84

Age months	Sex	Weight (kg)	Height (cm)	Indices		
				WFH	HFA	WFA
48	M	12.9	90	101	87	78
36	M	11.4	81	104	84	79
60	M	11.0	84	96	77	60
36	F	11.9	94	87	98	82
60	F	13.5	104	81	95	73
12	M	9.1	71	105	95	92
36	F	11.2	86	93	90	77
60	F	13.5	98	91	90	73
60	F	14	98	95	90	76
36	F	13	89	103	93	90
60	M	16	98	108	90	87
60	F	16	96	113	88	87
36	M	13	84	113	88	90
48	M	14	96	99	93	85
24	F	9	78	87	90	73
36	M	14	98	95	102	97
48	F	13	96	92	93	79
18	F	9	71	103	87	80
36	F	14	86	117	90	97
60	M	16	96	113	88	87
48	F	14	94	102	91	85
24	M	9	86	75	99	73
18	F	9	76	91	93	80
48	M	15	105	89	102	91
36	M	10.5	76	106	79	72
48	M	15	96	106	93	91
24	M	9	76	91	87	73
36	M	14	91	108	95	97
48	F	13	86	108	83	79
24	F	11	76	111	87	89
48	M	14	96	99	93	85
24	F	9	78	87	90	73
18	M	6	73	65	90	53
60	F	14	92	106	84	76
36	F	12	86	100	90	83
60	F	19	96	134	88	103
12	M	8	43	...	58	81
48	M	17	140	...	136	103
36	F	15	84	130	88	103
48	M	16	76	162	74	97
60	F	19	82	170	75	103
36	F	12	70	141	73	83
36	F	10	65	...	68	69
48	F	13	79	123	76	79
60	F	14	82	125	75	76
36	F	10	65	...	68	69
48	M	14	71	161	69	85
48	F	18	109	100	106	109
12	M	9	68	...	91	91
24	M	14	91	108	104	113

Age months	Sex	Weight (kg)	Height (cm)	Indices		
				WFH	HFA	WFA
48	F	20	110	109	106	121
36	M	12	92	91	96	83
60	F	16	70	188	64	87
36	M	6	55	...	57	42
48	M	10.5	64	...	62	64
60	F	12	75	124	69	65
36	M	9	71	103	74	62
24	F	5	59	...	68	40

Age months	Sex	Weight (kg)	Height (cm)	Indices		
				WFH	HFA	WFA
48	F	18.4	115	...	11	112
36	M	14.2	102	89	106	98
48	F	16.6	117	...	113	101
12	F	7.5	68	...	91	76
36	F	11.9	91	92	95	82
48	F	17.2	116	...	112	104
36	F	11.4	82.5	101	86	79
36	F	11.1	89	88	93	77
36	M	14.2	92	108	96	98
24	M	11.6	76	117	87	94
36	F	12.5	95	89	99	86
12	M	8.4	73	91	98	85
60	F	16	109.5	88	100	87
12	M	7.5	71	86	95	76
36	M	14.3	101	110	105	99
48	F	16.5	96	116	93	100
36	F	16.5	108.5	92	113	114
12	M	13.3	97	92	130	134
48	M	12	94.5	87	91	73
24	M	20.1	120	...	138	162
36	F	9.9	73	108	76	68
36	M	12.4	87	102	91	86
36	F	12.4	95	89	99	86
48	M	17.9	106.5	103	103	108
48	F	11.5	101	73	98	70
12	F	9	75	93	100	91
60	F	15	112	...	103	82
24	M	10	76	101	87	81
36	F	11.1	87	92	91	77
48	F	15.7	104	95	101	95
36	M	16.1	103	99	107	111
36	F	10.4	82	93	85	72
60	F	14.8	102	93	94	80
36	M	9.9	85	118	89	68
60	F	15.5	108	88	99	84
36	F	12.5	89	99	93	86
48	M	16.6	106	97	103	101
36	F	12.8	89	102	93	88
60	M	14.9	104	90	95	81
60	M	17	110	92	101	92
48	M	16.6	109	...	106	101
18	M	8.4	77	83	95	74
36	M	13.5	86	113	90	93
24	M	9.8	75	101	86	79
48	F	13.9	97	96	94	84
60	M	18.7	117.5	...	108	102
60	M	15.1	93	112	85	82
36	F	12.6	103	77	107	87
24	M	11.2	84	97	96	90
41	F	14.2	102	89	103	93

Age months	Sex	Weight (kg)	Height (cm)	Indices		
				WFH	HFA	WFA
48	F	14	98	95	95	85
18	F	8.2	78	79	96	73
48	M	12.2	91	94	88	74
36	M	13.3	101	85	105	92
60	F	16.5	105	98	96	90
24	F	10.1	78	97	90	81
54	M	13.9	103	85	96	80
18	F	6.8	65	...	80	60
48	M	11	85	94	82	67
24	M	8.8	72	98	83	71
36	M	10.2	89	81	93	70
24	F	12	89	95	102	97
48	M	10	78	96	76	61
36	F	12	89	95	93	83
48	M	16.1	112	...	108	98
36	M	11.2	86	93	90	77
36	F	9.8	76	99	79	68
60	M	15.5	107	89	98	84
48	M	10.8	82	96	79	65
60	F	16.1	103	99	94	88

Stratum 3 (Woyna Dega)

Children under 5 years of age

Age months	Sex	Weight (kg)	Height (cm)	"Indices"		
				WFH	HFA	WFA
12	M	9	73	98	98	91
30	F	12.2	88	98	96	90
60	F	13.9	100.5	90	92	76
36	F	11.9	89	94	93	82
12	F	8.5	72	94	96	86
54	M	15	102	94	96	86
54	M	15	96	106	90	86
48	F	12.4	84	108	81	75
36	F	8.2	71.2	94	74	57
48	F	15.2	100	99	97	92
24	F	12	80	111	92	97
24	F	9.4	79	89	91	76
18	M	8.1	76	82	93	72
60	M	14.8	98.2	100	90	80
48	M	11.3	85.0	97	82	69
36	M	10.4	84	90	88	72
48	M	10	84.5	86	82	61
30	F	9.5	83	83	90	70
48	M	8	73	87	71	48
24	F	17.1	102	107	117	138
36	M	12.1	81	110	84	83
36	M	11.5	82	103	85	79
60	F	13.2	87	109	80	72
36	M	10.4	85	89	89	72
48	M	12.9	97.9	87	95	78
48	F	16.6	105.8	97	102	101
36	M	12.6	83.5	110	87	87
36	M	15	105	89	109	103
60	F	16.2	110	88	101	88
48	F	15	105	89	102	91
48	M	14.6	101	93	98	88
24	F	12.0	83	105	95	97
60	M	13.1	95	94	87	71
48	M	17.3	97	119	94	105
24	M	14.6	104	88	119	118
60	F	12.5	87	103	80	68
48	F	15.6	98.5	105	95	95
48	M	12.2	89.5	96	87	74
24	M	11.2	83.5	97	96	90
60	F	17.8	108.0	101	99	97
48	M	10.2	79,5	95	77	62
60	F	15.9	105.6	93	97	86
24	F	8.1	73	88	84	65
60	M	7.5	75.5	77	69	41
36	M	9.9	86.6	82	90	68
60	F	17.0	108	96	99	92
48	F	17.6	115	...	111	107
36	F	12.5	85	107	89	86
60	M	16.5	110	90	101	90
60	M	15.4	100.5	99	92	84
48	F	11.6	88.5	93	86	70

Age months	Sex	Weight (kg)	Height (cm)	"Indices"		
				WFH	HFA	WFA
36	M	15.2	95.4	109	99	105
12	F	8.3	72	92	96	84
24	M	11.8	81	107	93	95
12	F	10.6	85.5	89	114	107
36	F	15.8	101	101	105	109
48	F	15.1	99	100	96	92
24	M	10.6	86	88	99	85
36	F	13.5	93.2	100	97	93
60	M	19.5	117	...	107	106
24	M	15.1	105	90	121	122
48	M	13.5	92	102	89	82
48	M	10.7	85	91	82	65
48	F	11.5	90	90	87	70
36	F	7.9	73	86	76	54
48	F	15.2	96	107	93	92
60	M	14.1	89	112	82	77
48	M	10.8	87	89	84	65
60	M	15.1	101	96	93	82
60	M	16.0	100.7	102	92	87
36	F	10.7	91.5	82	95	74
48	M	12.8	92.5	96	90	78
24	M	9.0	74.2	95	85	73
60	F	13.8	103	85	94	75
12	M	9.8	78	94	104	99
60	F	13.2	101	84	93	72
36	F	11.9	82	106	85	82
36	F	9.5	86	79	90	66
48	M	14.1	89	112	86	85
60	M	16.8	100	109	92	91
48	M	12.1	86	101	83	73
60	F	16.2	101	103	93	88
36	F	11.5	73	125	76	79
12	F	8	70	94	94	81
60	F	16.1	108	91	99	88
36	M	11.5	86	96	90	79
60	M	16.1	103	99	94	88
36	M	11.2	86	93	90	77
18	M	9	77	89	95	80
12	F	10.1	79	95	106	102
24	F	9.4	79	89	91	76
36	F	10.6	86.4	88	90	73
48	F	11.8	88	95	85	72
12	F	7.6	72	84	96	77
48	F	11.4	89	90	86	69
48	M	11.2	90	88	87	68
12	F	9	77	89	103	91
48	F	15.9	105.6	93	102	96
12	F	8.1	73	88	98	82
48	M	13.4	101.5	84	98	81
60	M	16.1	106	94	97	88
36	M	15.0	92	114	96	103

Age months	Sex	Weight (kg)	Height (cm)	"Indices"		
				WFH	HFA	WFA
36	F	13.3	94	97	98	92
60	F	18.7	111	...	102	102
48	F	11.7	96	82	93	71
48	M	12.5	96	88	93	76
36	F	7.9	72.5	87	76	54
60	F	13.6	90.5	105	83	74
48	F	10.8	90	84	87	65
12	F	8	88	65	118	81
60	F	15.9	105.6	93	97	86
48	M	11.2	88.5	90	86	68
48	M	12.5	92	95	89	76
12	F	7.4	66.0	...	88	75
36	M	10.6	85.6	88	89	73
60	M	10	84	87	77	54
12	M	7.6	69	...	92	77
30	M	9.6	79.4	91	86	71
36	M	9.5	76.5	95	80	66
60	M	15.5	103	95	94	84
48	M	12	85.5	101	83	73
48	M	9.2	77.5	90	75	56
60	M	13.9	103	85	94	76
36	F	12.3	93	91	97	85
60	F	15	103	92	95	82
42	F	14.7	95	105	95	95
36	F	11.5	87	95	91	79
36	F	9.7	80	90	83	67
36	F	11.8	92	89	96	81
24	F	8.5	79.5	79	91	69
36	F	10.5	80	97	83	72
60	M	13.7	92	104	84	74
36	F	11.4	88	92	92	79
60	F	14.5	83	127	76	79
36	F	9.5	80.5	87	84	66
60	F	12.6	84.5	109	78	68
60	F	15.5	92.5	117	85	84
12	M	10.1	77	100	103	102
36	M	11.7	90	91	94	81
24	F	10.6	85.5	89	98	85
36	F	11.6	91	89	95	80
24	F	9.5	77.3	94	89	77
36	M	11.5	85	98	89	79
36	F	11.5	90.5	89	94	79
12	M	9.2	80.5	84	108	93
36	F	10.9	83.5	95	87	75
36	M	10.5	85	90	89	72
60	M	14.7	100.2	95	92	80
36	F	10.4	82	93	85	72
36	F	11.2	83	98	86	77
24	M	8	69.5	...	80	65
60	F	13.2	90.6	102	83	72
24	F	8.2	71.2	94	82	66
60						

Age months	Sex	Weight (kg)	Height (cm)	"Indices"		
				WFH	HFA	WFA
60	M	14	99	93	91	76
36	F	9	82	80	85	62
60	F	14.6	101	93	93	79

ANNEX V
GENERAL ANTHROPOMETRIC STANDARDS OF REFERENCE USED [1]
(1) Weight for age 12 to 60 months, sexes combined

Age (months)	Standard Weight (kg)	Age (months)	Standard Weight (kg)
13	10.2	37	14.7
14	10.4	38	14.85
15	10.6	39	15.0
16	10.8	40	15.2
17	11.0	41	15.35
18	11.3	42	15.5
19	11.5	43	15.7
20	11.7	44	15.85
21	11.9	45	16.0
22	12.05	46	16.2
23	12.2	47	16.35
24	12.4	48	16.5
25	12.6	49	16.65
26	12.7	50	16.8
27	12.9	51	16.95
28	13.1	52	17.1
29	13.3	53	17.25
30	13.5	54	17.4
31	13.7	55	17.6
32	13.8	56	17.7
33	14.0	57	17.9
34	14.2	58	18.05
35	14.4	59	18.25
36	14.5	60	18.4

[1] Adopted from FAO, Human Nutrition in Tropical Africa, by M.C. Latham, O.B.E., Rome, 1979.

(2) Height for age 12 to 60 months, sexes combined [24]

Age (months)	Standard	Age (months)	Standard
12	74.7	37	96.6
13	76.0	38	97.3
14	77.1	39	97.9
15	78.1	40	98.4
16	79.3	41	99.1
17	80.5	42	99.7
18	81.4	43	100.3
19	82.7	44	101.0
20	83.5	45	101.6
21	84.4	46	102.1
22	85.4	47	102.7
23	86.3	48	103.3
24	87.1	49	103.8
25	88.0	50	104.5
26	88.8	51	105.2
27	89.7	52	105.7
28	90.4	53	106.2
29	91.3	54	106.8
30	91.8	55	107.3
31	92.6	56	107.9
32	93.3	57	108.2
33	94.0	58	108.5
34	94.7	59	108.7
35	95.3	60	109.0
36	96.0		

24 Ibid.

(3) Weight for Height for both sexes (70 to 110 cms) [25]

Length cm	Stadard Weight kg	Length cm	Standard Weight kg
70.0	8.5	90.0	12.8
70.5	8.6	90.5	12.9
71.0	8.7	91.0	13.0
71.5	8.9	91.5	13.1
72.0	9.0	92.0	13.2
72.5	9.1	92.5	13.3
73.0	9.2	93.0	13.5
73.5	9.4	93.5	13.6
74.0	9.5	94.0	13.7
74.5	9.6	94.5	13.8
75.0	9.7	95.0	14.0
75.5	9.8	95.5	14.1
76.0	9.9	96.0	14.2
76.5	10.0	96.5	14.4
77.0	10.1	97.0	14.5
77.5	10.2	97.5	14.6
78.0	10.4	98.0	14.8
78.5	10.5	98.5	14.9
79.0	10.6	99.0	15.1
79.5	10.7	99.5	15.2
80.0	10.8	100.0	15.4
80.5	10.9	100.5	15.5
81.0	11.0	101.0	15.7
81.5	11.1	101.5	15.9
82.0	11.2	102.0	16.0
82.5	11.3	102.5	16.1
83.0	11.4	103.0	16.3
83.5	11.5	103.5	16.4
84.0	11.5	104.0	16.6
84.5	11.6	104.5	16.7
85.0	11.7	105.0	16.8
85.5	11.9	105.5	17.0
86.0	12.0	106.0	17.1
86.5	12.0	106.5	17.3
87.0	12.1	107.0	17.4
87.5	12.2	107.5	17.6
88.0	12.4	108.0	17.7
88.5	12.5	108.5	17.9
89.0	12.6	109.0	18.0
89.5	12.7	109.5	18.2
		110.0	18.4

[25] Adopted from RRC, Standards for Community Survey on Nutritional Status, Addis Ababa, December 1987.