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estimation of crop areas and yields in agricultural statistics

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PREFACE

As determinants of crop production, statistics on crop areas and yields have been amongst the most important components of the international statistical activities of the Food and Agriculture Organization of the United Nations (FAO) since its inception. The compilation of national data on areas under crops and their expected yields presented a number of serious difficulties. Many developing countries had no data at all. In other countries, available data were often limited to a small number of basic cash crops with only vague information on other crops. In most cases, the quality of the data was questionable and their scope and coverage were severely limited. On questions such as gross and net areas planted, areas damaged, areas harvested, biological yield, harvested yield and economic data, etc., there was little information and its lack was strongly felt in a period of fast-growing interest in development planning and programmes.

One of the more widely used methods of collecting the data was, and continued to be, that of eye estimation of both the areas under different crops and the expected yield per unit area, a method which could result in somewhat reliable results, provided the investigators were highly experienced and a number of other criteria were observed. Data on areas under crops collected by interviewing a sample of holders were, in many countries, of doubtful accuracy unless the area data were based on cadastral maps and the farmers were able and willing to provide accurate information, which was often not the case, especially in developing countries.

Under these conditions FAO undertook systematic promotional work aimed at the establishment and the improvement of national crop area and yield statistics, especially for the more important crops. Both aims called for increased application of probability sampling techniques combined with objective measurement, especially in developing countries. Crop area and yield measurement in conjunction with appropriate probability sampling techniques is the best way of securing accurate data. However, objective measurement, even on a comparatively small sample, is a rather costly and time-consuming technique requiring highly qualified field staff, and hence it can be justified only in the case of the more important crops.

FAO programmes to promote the development of crop area and yield statistics took various forms. Seminars, training centres and international and regional meetings of experts were held to explain and discuss the problems associated with the uses of sampling methods and objective techniques of measurement in the collection of crop area and yield statistics. Technical assistance experts in agricultural statistics assigned to countries almost invariably had statistics of crop area and yield as a priority item on their programme of work. As part of these promotional efforts, the FAO published and widely circulated a number of publications and documents on the subject, especially the following:

1. "Estimation of crop yields", by V.G. Panse, published in 1954 and reprinted in 1964.
2. "Estimation of areas in agricultural statistics", edited by S.S. Zarkovich, and published in 1965.

These two publications have been extensively used and demand has been increasing for their updating and extension of their scope by inter alia, including new developments in the methodology and incorporating the experience gathered by technical cooperation experts. This provisional manual has been prepared to meet the demand for an up-to-date publication on the subject. Dr. J.B. Simaika, previously FAO Regional Statistical Adviser for Africa, served as a FAO consultant for this purpose. Comments on this publication for use in preparing a revised manual will be greatly appreciated and should be addressed to the Director, Statistics Division, FAO, 00100 Rome, Italy.

CHAPTER I. GENERAL CONSIDERATIONS

Importance of Reliable Estimates of Crop Production

1. Comprehensive statistics of a reasonable quality are one of the important requisites for the formulation and evaluation of development plans. The shortage of statistics and of other basic information is one of the main obstacles to more effective agricultural development planning, especially in the less developed countries. As agriculture is the predominant activity in most of these countries, high priority should be given to the development of agricultural statistics.

2. Two kinds of such statistics are required:

1) Data on agricultural structures which are generally collected through censuses of agriculture. Since the changes in structure are not generally very rapid (except when implementing agrarian reform), the information need not necessarily be collected on a yearly basis.

2) Data on agricultural production, utilization, prices, etc., items belonging to what is termed current agricultural statistics, which are to be collected through surveys on a continuous or seasonal basis, possibly several times during the agricultural year.

3. Reliable estimates of annual production of food crop and other agricultural commodities are assuming a rapidly growing importance, as countries make serious efforts to plan national development programmes to tackle the problem of feeding their populations and to raise their levels of living.

4. Time series of reliable data on crop production and its two components, areas harvested and yields per unit area, are essential for any rational development programme. The series are needed for a larger number of objectives, the most important of which are:

1) The determination of the cultivation plans at the national level (diversification of crop production) as well as at the individual farmer's level).

2) The elaboration and implementation of import and expert policies of agricultural commodities in cases of deficits and surpluses.

3) The formulation of price policies including those on subsidies as incentives to the improvement of crop production.

4) The zoning or regionalization of crop production according to the nature of the soil, the level of the yield, etc.

5) The establishment of a system for the equitable distribution of crop production over the different regions of the country.

6) The estimation of the contribution of agriculture to the gross domestic product and measuring the level of agricultural productivity.

5. Total production of a crop with any degree of reliability may be possible to obtain for those crops which are either marketed entirely or which the cultivation is limited to a few large estates (e.g. cotton, tea, cocoa, rubber). For such crops, accurate data can be obtained through marketing organizations dealing with the particular commodities or from the farms or estates which produce them. Even then, some parts of the production may be marketed outside the official channels and thus result in an under-estimation of total production.

6. For the large majority of crops and especially staple food crops which are usually grown by millions of farmers in scattered holdings, a complete enumeration for measuring their annual production is impossible. A practicable approach to the measurement of production "P" of such crops is to consider the two components of total production of a crop, namely the area "A" under the crop and the yield per unit area "Y", and either measure or estimate separately each of them; the product of the two then gives the total output of the crop: P=AY.

7. For certain crops, especially tree crops, the production is estimated either through the number of productive trees and the yield per tree, or through the following three components of production: area "A" of compact plantations, density (number of trees, plants, stands, etc.) "D" per unit area and yield "Y" per tree (or plant, stand, etc.). The three components are then measured or estimated separately and the product P=ADY is then calculated.

A Permanent System to Collect the Needed Data

8. For development planning purposes, the production data including data on crop areas and yields are not sufficient if only given at the national level. The statistics have to be disaggregated in various ways in order to satisfy the needs of the different users. They have to be disaggregated

- by region (physical, administrative, ecological, etc.) to permit regional planning;
- in time: for each agricultural cycle separately showing the succession pattern within the year as well as the crop rotation from year to year;
- according to its utilization, either as auto-consumed and marketed or as seed, feed, stocks, food use and industrial uses.

Moreover, other production related data on the volume of existing stocks and the rates of waste (pre-harvest, harvesting, transport, storage, etc.) are also needed.

9. Similarly, the data on crop areas and yields have to be disaggregated especially according to the different types of inputs: water (rainfed, irrigated and method of irrigation), types of seeds (local, improved and high yielding varieties), types and amount of fertilizers (N, K, P and their combination and ratios), treatments (pesticides, insecticides, etc.) and mechanical and labour inputs. Crop area and yield data by size of holding and sometimes by other characteristics, such as land tenure or legal status are also essential in planning agrarian reform and rural development.

10. Reliable statistics of crop production even when they are timely, i.e. when available soon after harvest, do not always satisfy the needs of planners and policy makers, especially those who are concerned with export policies or with import measures to supplement the production of those food crops and other agricultural commodities, the output of which is known to be below the demand. Some kind of reasonable forecast of the production or at least some order of magnitude of the expected deficit or surplus is needed several months before harvest for important crops.

11. From the above, it is clear that the collection of reliable statistics on crop areas, yields and production is a permanent activity and has to be organized on a continuous basis within an integrated system for the collection of agricultural statistics. In the proposed system, the collection of the data on crop areas and yields will be an integral part of the responsibilities of the outposted statistical officers and agents in the regional or provincial offices. They will have to measure and/or estimate the crop areas; estimate the expected yield and report on crop conditions. The reports could be periodic (e.g. monthly) or distributed in time depending on the phenological characteristics of the crop.

12. The statistical field reports should be presented in a unified tabular form (maybe one schedule per crop) and in such a way as to make their processing (either manual or mechanical) as simple as possible. Each report should contain the appropriate data on area (tilled, sown, damaged, expected to be harvested and harvested); on the current crop husbandry activities; on the different inputs, and on the estimated expected yield.

Problems of Estimating Crop Areas and Yields

13. The problems of estimating crop areas and yields differ in nature depending on the methodology used in the collection of the basic information. Problems encountered in complete enumeration are different from those met when sampling techniques are utilized. Different types of problems arise when the data is gathered through a field reporting system, eye estimation or interview of the farmers or when objective methods of measurement are used.

14. Moreover, some problems are related to the level of statistical development in the countries and in particular the educational level of the field reporters, the statistical investigators and the respondents. Other problems are due to the local practices of crop cultivation and also to the type of crop or crops under study. Also, the estimation of areas creates problems which are sometimes different from those met in the estimation of yields.

15. Problems of comparability over time (e.g. from year to year), or over space (between regions within the country or between countries) further complicate the situation. They are generally due to a lack of uniformity in the application of the recommended concepts and definitions. They may arise either from misunderstanding and wrong interpretation or from voluntary changes (which could even be improvements) introduced in the concepts and definitions.

16. The main problems encountered in the estimation of crop areas and yields are enumerated in some detail below. Recommended action to be taken when such problems are encountered is implicitly or explicitly given in the appropriate sections of the Manual.

17. To collect statistics on a yearly (or more frequent) basis of crop areas, yields or productions (usually using eye estimates) through complete enumeration of millions of farmers dispersed over the country is a very difficult task even for statistically developed countries. Such complete enumeration is feasible only if the number of enumeration units is reasonable (limited to some hundreds or a few thousands). For this reason the data collected is usually related to larger units of enumeration, such as administrative or ecological subdivisions of the country. When the size of the unit is large the problem of the estimation of the crop areas to be harvested and also the estimation of the average yield over the whole area would be at best a subjective judgement.

18. When sampling techniques are used, the problems encountered are the well-known problems inherent to sampling, especially those relating to

- the frame, accuracy and completeness, area sampling versus list sampling, etc.
- multi-stage schemes, number of stages, stratification, type of enumeration units and their construction, methods of selection
- size of sample, methods of estimation, errors or deviations due to sampling, biases.

These are in addition to non-sampling errors which are common to other data collection methods.

19. Problems of field reporting include those created by the size of the enumeration unit as mentioned in para. 17. Even when the total size of the unit or the size of the cultivated part of the area is known, the subdivision of the total area into the component areas under the different crops is a problem. On the other hand, the estimated average crop yield can be subject to different types of biases. When the reporter is an "extension officer" who might feel that his or her technical assistance to the farmers should show "good results" he or she is liable to over-estimate crop yields. Estimates of crop yields made by a "neutral" investigator (or voluntary reporters) will tend to show a regression towards a known normal average, i.e. the investigator will under-estimate the true yield in "good" or bumper years, bringing it nearer the average, and will over-estimate it in "bad" or deficit years.

20. Eye estimation is at best implicitly and hence necessarily based on some kind of arbitarily selected sample (usually a judgement sample) since generally the investigator does not eye-estimate all the areas and all the yields of all the fields and all the crops in his or her area of assignment. Moreover, a reasonably accurate eye estimate of an area or a yield implies a deep knowledge and a wide and long experience of the investigator. Similarly, judgement and eye estimates of crop areas and yields by locality chiefs or other knowledgeable persons of the locality are subjective and their quality will depend on the level of knowledge and experience of the person who makes them.

21. The interview method, in the case of continuing investigation of crop areas and yields, can only be used in sample surveys and thus presents the same problems spelled out in para. 17. Other specific problems are those relating to the questionnaires or forms to be used, to the interviewer and to the respondent. One of the questionnaire problems refers to the dilemma: individual crop or collective crop questionnaire. In the first case, a special form is used for each crop and at each round the interviewer records on it all the relevant information, while in the second case at each round a new form is used on which all the information on all the crops is recorded. The main problem relates to the interviewer's error which is known to exist and should not be under-estimated, but the assessment of which is very difficult to carry out. Problems relating to the respondent are due either to inability of the respondent to provide the information especially because of lack of knowledge and/or deliberate unwillingness to declare the correct figures. In general, they tend to purposely under-estimate areas or production to avoid taxation or other government crop procurement regulations or over-estimate areas or production in the case of crops encouraged by the government through incentives.

22. The estimation of crop areas in holdings, even when cadastral maps exist, is not an easy task. The total area and also the areas of the different blocks may be shown on or easily estimated from the maps. However, since the maps are generally old and are not up-dated, the area data are not always accurate. The areas of fields and plots under different crops change from year to year, and have to be estimated subjectively or measured.

23. Measuring areas is a difficult, costly and time-consuming undertaking. The investigators have to be well trained on surveying techniques and on the proper use of the necessary equipment. The shape of the fields, especially in developing countries is not always polygonal but often a curvilinear closed figure, which has to be reduced to a polygon, with a small number of sides (e.g. less than 20), of an equivalent area. Measuring errors can be introduced by the surveyor or are inherent to the equipment used.

24. Nevertheless, the objective method of measuring areas gives the most reliable data on crop areas. However, statistics of total crop areas, when using this method, will still be biased and under-estimated if the farmer does not declare and/or show to the enumerator all his fields and also in the case where the enumerator omits to measure those fields which are situated far away and difficult to reach.

25. The use of objective methods to measure crop yield presents other types of problems. When this is done through crop-cutting plots, the problems relate to: size and shape of plot, method of selection of the plot to be crop-cut, the period in which the plot is delineated, the necessity to harvest the plot at exactly the same time of harvesting the entire field and using the same procedure as the one used by the farmer himself. When the estimation of the yield is through measuring the production of a sample of trees (plants, stands, etc.) the problems relate to the size of the sample of trees, the method of selection of the sample and the right period of harvesting and measuring the production. In both cases, there are also problems relating to driage of crops or maturing of fruits when the final production data relate to these states of the crops.

26. In collecting and reporting statistics of crop areas, the most commonly used area units are the hectare and the acre. However, in some countries the unit used is purely national or sometimes sub-regional (a small group of countries) (see para. 37). This does not pose any problem as long as the national unit can be converted to the standard units and the conversion factor is fixed once and for all. A serious problem exists when measuring units with different names are used locally in different regions within the same country and when no fixed conversion factor is known. A still more serious problem is encountered in countries where a measuring unit with a specific name has different dimensions in different parts of the country and, naturally, these dimensions are not known.

27. Similar problems are met in collecting statistical information on crop yields or production. The measures of volume or weight used and reported by the farmers are generally based on some kind of local container (sack, basket, kerosene tin, etc.) and, given the variety of forms, sizes and capacities of the containers, it is quite difficult to convert them into standardized units.

28. In hilly regions, when crops are grown on slopes which could be quite abrupt (more than 20%), the evaluation of the crop area is not simple. The crop area should not be the physical area measured on the slope (the inclined plan) but its projection on a horizontal plane. This is due to the fact that plants and trees grow vertically and not perpendicularly to the slope and thus require for their growth some kind of vertical cylinder of soil. If the crop area is measured on the slope and not projected horizontally, crop areas could be significantly over-estimated.

29. Mixed cropping is a common practice especially in developing countries. The problem of estimating crop areas in this situation gets more and more complicated as the number of crops in the mixture or in association increases (in some cases more than 10 crops are grown in the same field) and especially when the proportions of the different crops in the mixture vary from field to field. Moreover, the vegetative cycles of the crops may have different lengths (from less than three months to more than a year) and the crops may have different periods of sowing, planting and harvesting. Thus, the number of crops in the same field may vary according to the period of the year and the time of the enumerator's visit. The allocation of areas to the component crops is a complex undertaking. Thus, the problems in estimating crop yields in the case of mixed cropping are more complicated than those encountered in the case of crops in pure stand.

30. In some countries and for certain crops (like vegetables) continuous planting of the same crop or of similar crops in the same field is common practice. In some cases, the crops are planted successively in different parts of the field (e.g. successive fringes are planted from the outer borders of the field and gradually reaching its centre, following the area left by receding water line) or the new plants are intercropped with the older ones or, after uprooting those plants that have already been harvested. In the latter case the problems are similar to those of mixed cropping and, in the former, similar to, but more complicated than those of successive crops and where cropping intensity (ratio between total area cropped and physical area) is of great statistical interest. Continuous planting implies continuous harvesting and introduces additional problems to the estimation of the yield. Such problems are enumerated in the following paragraph.

31. Certain crops are not harvested in one single operation but the produce is left in the soil or on plants and trees and is continuously harvested at regular or irregular intervals during a long period of time (e.g. cassava, some fruits and vegetables). Moreover, for certain crops the produce is not completely harvested, but some of it is either kept as a kind of reserve from which to draw if the need arises or even left over to rot (e.g. cassava, plantain). The estimation of crop areas in such cases does not present any particular problem, but the difficulty lies in how to estimate yield and/or production. Continuous estimation of the volume of the crop harvested is not feasible. An estimation based on a one-time harvesting operation may lead to an under-estimation of yield and production if the crop is expected to produce more during the period following the time of estimation. On the other hand, it may lead to an under-estimation of yield and production if, normally, the crop is not completely harvested.

32. The problem is further complicated in the specific case of cassava (a staple food product in many developing countries) and similar crops where, besides the practices of continuous planting, continuous harvesting and partial harvesting, the crop occupies the soil for more than one year (for cassava from 18 to 36 months) and where the volume and weight of the product gradually increase. Now, since the time reference period for current statistics of crop production is the agricultural year, the problem arises of how to allocate the area, yield and production (which yield and which production) over the long period of soil occupation.

33. The practice of shifting cultivation is gradually disappearing, however, there are still a number of countries in which the system still exists. Agriculture is generally carried out on a communal basis and in such a case the procedure could be summarized as follows. Each year, the adult members of the community clear a new segment of the forest which is then subdivided into individual fields. As an illustration, the system practiced in some African countries is as follows: The first year the land is planted uniformly with the same crop, generally a cash crop like cotton. The second year one or two essential crops (e.g. cereals, groundnuts) are planted. During the third and fourth year different complicated crop mixtures, but generally including cassava, are planted. After the fourth year the land is abandoned. Besides the above problems of mixed cropping, continuous planting and harvesting and partial harvesting, the problem of land use categories is added specially in relation to the abandoned land. The classification of the abandoned land is difficult since it may be used as a reserve stock of cassava or used as pasture land for a period of time, then it would get more and more bushy until some 10 years later when it might be cleared again and cultivated.

34. From the difficulties presented above in paragraphs 29 to 33, it is clearly seen that the two concepts: area and yield, or alternatively area and production, do give an incomplete picture of the agricultural situation of crop production. Taking into consideration the factor "time" or "period of soil occupation", those indicators like "cropping intensity" or "land productivity" will have much more meaning and usefulness. Studies to investigate this aspect of agricultural statistics and the possibility of introducing a new parameter or concept related to the period of soil occupation was recommended in the FAO Regional Seminar on the Methodology of Agricultural Surveys. [13] *.

Concepts and Definitions of Crop Areas and Yields

Areas [1]

35. Concepts and definitions of Area in agricultural statistics depend on the use to be made of that area. For example, FAO recommends [8] the use of the concept "gross area" (see para.58) in the collection and publication of statistics on land utilization categories while it recommends the use of the concept "net area" (see para 58) when dealing with crops and their yields. However, in practice many countries have used indifferently one or another of the concepts and very often without its being appropriately qualified or defined. This situation calls for clarification of the concepts and definitions and harmonization of the practices if comparability of area statistics between countries is to be secured.

* Figures between square brackets represent the serial number of the publication in the List of References and Selected Bibliography

36. The definition of "area" can be taken to be "a particular extent of the earth's surface". However, for purposes of agricultural statistics, this definition should be supplemented to take into account the difficulty mentioned in para. 28. Thus, the definitions would read: "the horizontal projection of a particular extent of the earth's surface" and would thus represent the area as shown on cadastral maps. This modification will ensure that the total area is equal to the sum of the component areas which is not the case when areas are measured on slopes.

37. Crop area statistics are not always reported in metric system units (hectares, ares and square metres (see para. 26)). Different units have been used in different parts of the world and some of them together with the corresponding conversion factor to hectares, are given below:

Countries	Name of Unit	Hectares
Colombia	Fanegada	0.64
Members of the Commonwealth	Acre	0.4047
Egypt, Sudan	Feddan	0.4208
Ethiopia	Gasha	40 (approx.)
Guatemala	Manzana	0.6987
Hungary	Kathold	0.5755
Iraq	Meshara	0.25
Japan, Rep. of Korea	Cho, Chungo	0.9917
Jordan, Lebanon, Syria	Donum	0.1000
Mauritius	Arpent	0.4221
South Africa	Morgan	0.8565
Thailand	Rai	0.1600
Turkey	Decars	0.1000

38. In censuses of agriculture and in agricultural surveys where the unit of enumeration is the holding, the first concept is that of total area which is defined as the sum of all the land reported as being under operation by the holding. It is to be noted, however, that the sum of the total area of all the holdings in a country and its breakdown in land use categories is not equal but smaller than the total cadastral area of the country and the corresponding holdings.

39. An insight into the basic structure of agriculture can be obtained if the total area of the country is broken down according to the classification known as land utilization. The purpose of this classification is to show what part of the total land in a given country can be used for different types of agricultural production.

40. The breakdown of the total area according to categories of land utilization shows the potentialities for various types of agricultural production and makes possible comparisons between countries in this respect. Information on land utilization by administrative units within a country shows how the possibilities of various types of agricultural production are spread over the national territory.

41. The broad categories of land utilization recommended by FAO are:

1. Arable land
2. Land under permanent crops
3. Land under permanent meadows and pastures
4. Wood and forest land
5. All other land

42. Arable land refers to all land generally under rotation whether it is under temporary crops, left temporarily fallow or used as temporary meadows. In some countries the term "arable land" also includes land under permanent crops, and other countries may also use this term in a different sense. It is essential that their national reports indicate clearly the definition used. Total arable land may be divided into the following four classes:

1. Land under temporary crops
2. Land under temporary meadows
3. Land temporarily fallow
4. All other arable land

43. Land under temporary crops includes all land used for crops with a growing cycle of under one year, sometimes only a few months, which needs to be newly sown or planted for further production after the harvest. Crops remaining in the field for more than one year should also be considered temporary crops if harvesting destroys the plant (e.g. cassava and yams). Crops grown in rotation and therefore destroyed when the land is ploughed (e.g. alfalfa, clovers and grasses) should be considered temporary crops. Asparagus, strawberries, pineapples, bananas and sugarcane, for example, are sometimes grown as permanent or biennial crops and sometimes as annual crops, the respective areas should, therefore, be classified as under temporary or under permanent crops as the case may be.

The specialized cultivation of vegetables, flowers, bulbs, ornamental plants, and kitchen and market gardens (including cultivation under protective cover, e.g. glass or plastic) should also be included in this category; however, land under trees and shrubs producing flowers, such as roses and jasmine, should not.

44. Land under temporary meadows and pastures is the land temporarily cultivated with herbaceous forage crops for mowing or pasture. Because some practical difficulties may arise in differentiating temporary meadows from permanent meadows and pastures (see below), it is suggested that such crops cultivated for a period of less than five years be considered temporary. Some countries use different criteria, and a few countries do not distinguish between temporary and permanent meadows or pastures. National procedures should be clearly indicated in the reports.

45. Land temporarily fallow is land at rest for a period of time before it is cultivated again. If the land remains fallow too long, it might acquire certain characteristics which would determine its inclusion in other major land-use groups, such as "permanent meadows and pastures" (if it could be used for grazing) or "wood or forest land" (if it has become overgrown with trees that could be used as timber, firewood, etc.) or "all other land" (when it becomes waste land). A maximum period of idleness, probably less than five years, should be specified. On the other hand, a piece of land should not be considered temporarily fallow unless it has been or is intended to be kept at rest for at least one agricultural year. If the time reference for the data falls at a time when sowing or planting has not been completed, the area lying fallow at that time which will be put under crops soon afterwards should be classified by the crops to be sown or planted and not as fallow land. Fallow land that is temporarily used for grazing should be classified as fallow if the land is normally used for the cultivation of temporary crops.

46. The category all other arable land includes all rotation land not put to any of the uses mentioned above during the reference year, such as arable land temporarily damaged by floods, land prepared for cultivation but not sown because of unforeseen circumstances and abandoned land.

47. Land under permanent crops signifies land cultivated with crops which occupy it for a long period of time and which do not have to be planted for several years after each harvest. Land under trees and shrubs producing flowers, such as roses and jasmine, is so classified, as are nurseries (except those for forest trees, which should be classified under "wood or forest land"). Permanent meadows and pastures are excluded.

48. Land under permanent meadows and pastures means land used permanently (i.e. for five years or more) for herbaceous forage crops, seeded and cared for or growing naturally (wild prairie or grazing land). Permanent meadows and pastures on which trees and shrubs are grown should be recorded under this heading only if the growing of forage crops is the most important use of the area. Since some countries do not distinguish between temporary and permanent meadows or pastures, clear indication of national practices in the reports is essential (see the definition of land under temporary meadows and pastures above).

49. Wood or forest land includes all woodlots or tracts of timber, natural or planted, which have or will have value as wood, timber or other forest products. Nurseries of forest trees should also be classified under this category. Wood or forest land used only for recreation purposes should be reported instead under "land not elsewhere specified". In either case, the areas should be reported to enable reconciliation with other land use classifications.

50. All other land includes all other land not elsewhere specified, whether potentially productive or not. Some countries may wish to subdivide this class into potentially cultivable and uncultivable. Generally it refers to unused lands and areas under buildings, roads, parks, etc.

51. If data on areas are collected at a given point of time, such as the harvest, and broken down by the classifications presented above, a very useful picture of the country's agriculture results. However, this information is insufficient for various studies of the economy of crop production. For example, in productivity studies it is useful to know, in addition to the area harvested, what part of each crop was damaged or used for other purposes before the harvest. To advise agricultural producers before their production plans are finalized on the possibility of gains by increasing the area planted, it is useful to know more about planting intentions. To study the benefits of irrigation it is necessary to collect data on irrigated areas under each crop.

52. The following additional concepts might therefore be useful in considering the programme of area statistics:

1. Area intended for planting (or sowing). The information refers to area that the holders plan or intend to put under various crops. It is obvious that the actual planted area can be considerably different. Data involved are collected before the planting starts.

2. Area tilled shows at a given point of time the part of arable land on which work has been done to fit it for raising crops. The work involved is ploughing, harrowing, manuring, etc.

3. Area planted (or sown). This concept refers to areas actually planted with some specified crop. Data collected for separate crops on area planted make it possible to have in advance a basis for a rough estimate of the production.

4. Area damaged (as a result of floods, rain, winds, ice, insects, etc.) gives an account of losses due to the effect of unfavourable factors.

5. Area abandoned for different reasons, such as difficult meteorological conditions. Areas are sometimes abandoned if it is clear that there is no point in putting further work in the crop concerned on account of the expected poor harvest.

6. Area harvested refers to the area from which the crop was actually harvested and is one of the most important concepts in area statistics. Harvested areas represent a basis for estimating total production. Statistics on crop areas normally refer to areas harvested.

53. Improvement of crop production through the introduction of a number of inputs makes it imperative to classify and tabulate the data on the production, the yield and the cropped area according to the type or types of inputs. Besides labour inputs, the main inputs utilized to improve production are: irrigation, fertilizers, manures and soil dressings, pesticides, improved seeds and high yielding varieties. In order to study the benefits gained through the use of the different inputs, it is necessary to collect data separately on the areas with and without the above inputs.

54. Area normally irrigated refers to the gross area of land normally provided with water other than rain for improving the production of crops or pastures. The uncontrolled flooding of land by the overflow of rivers or streams should not be considered irrigation. However, when rain water or water from uncontrolled overflow of rivers and streams is collected and later used for irrigation, this practice should be considered irrigation. Land irrigated more than once during the agricultural year should be counted only once. The total of the areas irrigated and the areas not irrigated should be equal to the total area of each land-use category.

55. Area treated with fertilizers, etc: An area treated more than once with the same kind of fertilizer applied to the same crop or group of crops cultivated simultaneously on the same land is to be reported only once. However, if it were applied to different crops grown successively in the year on the same land, the area should be reported for each crop separately. An area receiving more than one kind of chemical inorganic fertilizer should be reported only once in reporting the total area treated with chemical inorganic fertilizers.

56. Area treated with insecticides or pesticides is to be reported only once even when the treatment has been repeated several times as long as the different applications were on the same crop or crops. However, if it were applied to different crops grown successively on the same land, the treated area should be reported for each crop separately.

57. Area sown with improved seeds or high-yielding varieties should be shown separately from the area sown with local seeds and, when possible, by variety. Generally this is too complicated and the sown area could be classified into three classes according to the type of seeds: indigenous (local), improved (hybrid, etc.) and high-yielding varieties. It might also be difficult to distinguish between the improved seeds and the high-yielding varieties and, in that case they should be presented as one single item.

58. Two other important concepts of area, the one including and the other excluding uncultivated patches, bunds, foot paths, ditches, headlands, shoulders, shelterbeds, etc. are those designated by gross area and net area respectively. It is recommended to use gross area when dealing with land use categories and net area when estimating crop areas, yields and production. However, when estimating production through the product of area and yield per unit area or the product of area, density and yield per plant (or tree, etc.) the essential point is that the multiplicants should correspond to the same characteristics of the area. Thus, if the known or measured data relate to gross area, the yield or the density should be estimated or measured on a gross area basis.

59. In some countries and under favourable climatic conditions, crops, either the same or different ones, are shown or planted and harvested more than once in the same field during the agricultural year. This practice of cultivating during different periods of the year, different or the same crops on a field is called successive cropping. Successive cropping is of great importance in countries with more than one cropping season. The field or parts of it may also be left fallow during one or more of the cropping seasons, or it may be sown or planted and harvested during each cropping season in the same agricultural year. The area of successive crops is to be reported for each crop separately for each time the area is sown or planted during the agricultural year. Thus if two different crops are grown one after the other on the same field, the area of that field will appear twice in the results, once under each of the two crops concerned and sometimes more in countries having more than two cropping seasons. Similar counting of areas also occurs if the same crop is grown successively during the agricultural year. Thus the total of reported crop areas for the agricultural year may be, and usually is, larger than the total physical area of the holding. However, successive gathering of crop products from the same standing crops should not be confused with successive cropping. The areas for the former should be reported only once unless the same crop is sown or planted and harvested more than once during the agricultural year.

60. In some countries, the practice of growing simultaneously two or more different temporary and/or permanent crops on the same field or plot is frequently used. Crops cultivated in such a way are called mixed or associated crops. The number, kinds and proportions of the crops in the mixture or association will generally vary according to the prevailing practices in various regions within the country and to other factors such as meteorological conditions. In estimating crop areas in such cases, it is desirable to estimate the area which each crop would have covered if it had been grown alone (pure-stand equivalent area). Various methods may be devised for estimating the area to be assigned to individual crops in the mixture. Some of these methods are proposed in the related section in Chapter V.

Yields and Production /2/

61. In agricultural statistics the concept of yield has been generally used to represent the average amount of produce obtained per unit of crop area, while the concept of production covered the total amount produced. However, in some cases of tree crops, the concept of yield covered the average amount of produce per tree (stand, hill, etc.) and the production has been calculated as the product of the average yield per tree and the number of producing trees, etc.

62. As already mentioned in para.58 above, for the estimation of production as the product of area and yield, the characteristics of the yield should correspond to those of the area. Thus, to each concept of area will correspond a parallel concept of yield and there is no need to go into these concepts another time. The following list gives the most important related concepts of area and yield:

Area	Yield
total crop area	average crop yield
irrigated crop area	yield of irrigated crop
fertilized crop area	yield of fertilized crop
crop area treated with pesticides, etc.	yield of crop treated with pesticides, etc.
crop area sown with local variety seeds	yield of local variety
crop area sown with improved variety seeds	yield of improved variety
gross crop area	yield based on gross area
net crop area	yield based on net area

63. Other yield concepts are specific to the type of yield under consideration but are independent of the concept and the method used in estimating or measuring the crop area, i.e. each of these concepts of yield can correspond to all kinds of concepts of crop area, but to each of these concepts is attached a similar concept of total production. Since some countries use some of these concepts indiscriminately, which could be a source of confusion, an attempt to clarify and distinguish amongst them is given below.

64. The potential yield or production is a static concept. The estimation of such a yield is based on:

- the characteristics of the soil on which the crop is grown,
- the type and amount of seeds,
- the type and amount of inputs

and on the assumption that the weather and other climatic conditions will be normal. The estimation of the potential yield is generally carried out very early in the crop growing season, e.g. after sowing or planting.

65. The expected yield or production is a more dynamic concept since the expected yield can be and generally is estimated at different times during the growing cycle of the crop. The bases of estimation include the three above-mentioned ones, namely soil, seeds and inputs, but more specially:

- the conditions of growth of the crop (size, height, state of health, attack, etc.)
- the actual weather and other climatic conditions

66. The biological yield or production is a "gross" yield or production. It is based on the assumption that all the produce will be harvested, and that pre-harvest losses, which may have occurred, have been taken into account, while harvesting and post-harvest losses are non-existent.

67. The harvested yield or production is the actual quantity of the produce obtained after harvesting. Harvesting losses which may differ according to the method used (manual, machine, etc.) have already been taken into account, while post-harvest losses are not. The produce may or may not have been cleaned, winnowed, etc. and generally the moisture content is higher than the acceptable level.

68. The economic yield or production is the actual quantity of the produce which reaches the customer. All types of losses: pre-harvest, harvesting, post-harvest including processing, transport and storage losses have been deducted. The crop has been dried and moisture content brought to the right level. The produce has been threshed, winnowed, dehusked, shelled or otherwise processed and prepared for sale or consumption. This concept of yield and production is the most useful from the point of view not only of the economist, but also of the traders and the consumers.

Sources of Data on Crop Areas and Yields

69. It might be useful to describe briefly the major sources through which statistics on crop areas, yields and production are obtained or collected at the national level and the published form in which the data is presented. The main national sources are:

- administrative records
- specialized agricultural agencies
- field and administrative reports
- agricultural censuses
- agricultural surveys
- agricultural research stations
- statistical publications

70. In almost all countries of the world Ministries of Agriculture and/or Central Statistical Offices keep records of the time series on crop areas, yields and production. These records cover generally all the crops in the country or they may be confined to the industrial crops, the cash crops and the most important of the food crops. Generally a breakdown of the data by large administrative subdivisions of the country or by ecological zones is shown and, in some cases, the breakdown is also given for the different varieties of the crop and/or for the different types of inputs (irrigated or not, fertilized or not, etc.).

71. Another administrative register of great importance to statistics of crop areas is the land cadastre in which the extent, value and ownership of real property is registered together with the related mapping material. From the map, the areas of the different parcels of land are known, but not the particular crop areas specially in the case where the parcel is subdivided into a number of fields planted with different crops. In some countries the farmers have to report annually the crop areas and, in that case, the crop areas are also registered and updated yearly in the cadastre. Unfortunately very few of the developing countries have such cadastres.

72. In many countries specific agencies, boards, corporations, etc., have been set up by governments to deal with one particular crop (cocoa, tea, etc.) or a group of crops (cereals, fruits, etc.). These agencies' main activities cover the distribution, marketing and storage of the related crop or crops. They also intervene or advise on price-fixing and the award of subsidies to farmers. For this they keep records of planted areas, harvested areas, expected yields, actual production, amounts of stocks, etc. of the particular crop or crops. Other national agencies which keep statistical records of crop areas, yields and production are the agricultural production and/or marketing cooperatives, the agricultural credit banks, etc.

73. In order to develop and improve agricultural production, ministries of agriculture in most countries have established a network of regional offices well staffed with agronomists, extension workers, etc. whose main activity is to give technical assistance to the farmers. An integral part of the duties of the outposted personnel is to prepare periodical reports on the state of agriculture and especially agricultural production in their area of assignment. Generally a large section of these reports deals with statistical data on crop areas, crop conditions, inputs utilized, occurrence of pest attacks, natural calamities, etc., expected yield and production. The reported data are generally used by the statistical division in the ministries of agriculture as a base for the elaboration and estimation of the official data on crop areas, yields and production. In some countries the periodical reports on crop areas and production are made by the administrative officers in small administrative subdivisions (superintendents in sub-parishes, village chiefs, etc.) and then communicated to either the central or the regional statistical offices.

74. The census of agriculture is meant to provide statistics relating mainly to the structure of agriculture and to the use of agricultural resources. It is the principal statistical operation for obtaining comprehensive and up-to-date data on agricultural land area and its subdivision into land-use categories, on crop areas and on the use of the different inputs. The census provides the essential data not only for the country as a whole, but also for adminsitrative subdivisions and, whenever possible, for agro-ecological zones and other small areas (e.g. localities).

75. Statistical data on crop areas, yields and production of a comparatively good quality and greater reliability are obtained through continuing sample surveys. The method of collecting the data may vary according to the level of statistical development of the country concerned from the simple and low-cost method of self-enumeration to the costly and more complicated method of measuring crop areas and measuring the yield in representative crop-cutting plots. Area sampling and point sampling have been used in countries where good up-to-date mapping material or aerial photographs exist, otherwise multi-stage sampling with farmers and fields as statistical units (at one stage or another of the sampling scheme) have been utilized. Chapter II of this manual deals, inter alia, with the methodology of sample surveys for the estimation of crop areas, yields and production.

76. Statistics of crop areas, yields and production can be found in national publications such as statistical bulletins issued monthly or quarterly, statistical yearbooks and/or agricultural yearbooks, special reports on agricultural conditions and developments, and in releases on forecasts of areas and yields. In regular publications, the data is given at the national level and also for large administrative or agro-ecological subdivisions of the country. The usual practice is to present, besides the data on the current or latest available year, an historical series on the performance of the crops during the previous period which may range from 2 to 10 years.

77. Area and yield statistics are also available from the publications of the regional and international organizations having interest in agriculture. Such organizations may be international commissions and agencies which collect, evaluate and publish area statistics on a regional or worldwide basis. They may limit their scope to particular crops grown all over the world or to a few commodities in a particular region. For instance, the International Wheat Council and the International Tea Committee are concerned, as their names imply, wholly with one crop grown in the principal producing countries of the world. The Commonwealth Economic Committee includes, in its annual publication, statistics for a group of allied commodities grown in the principal countries of the world, with special reference to the Commonwealth countries. The United States Department of Agriculture (USDA) is another source which issues "world summaries" at regular intervals, including area and yield statistics relating to specified crops, showing continental and world totals.

78. The Food and Agriculture Organization of the United Nations (FAO) is another important international source of information relating to area, yield and production statistics on almost all the crops grown in the world. FAO's Monthly Bulletin of Statistics contains tables on area, yield and production of specified crops by the principal producing countries. The continental, regional and world total are also given. The tables in FAO's Production Yearbook, however, contain much more data than those in the Monthly Bulletin. the Yearbook also includes data for all producing countries in the world and covers crops which are not included in the Monthly Bulletin.

CHAPTER II. CONDUCTING CROP AREA AND YIELD SURVEYS

Components of a Programme for Crop Statistics

79. Crop areas, yields and production are only part, although most important, of a system of data on crops and related agricultural operations. Data on crop areas, yields and production are important not only in themselves but also in relation to statistics on many other topics some of which are even not considered agricultural in nature. The topics on which information is needed for a comprehensive and analytical study of the characteristics of a crop area, yield and production alone are too numerous to be enumerated here in a satisfactory systematic manner. They cover such topics as:

Special agricultural techniques (including crop rotation, order of planting crops and crop succession within the year, crop mixtures and use of shifting cultivation),

Agricultural operations (including land preparation, sowing and planting, or transplanting, crop husbandry, harvesting and preparation of crop for marketing);

Material inputs (including seeds and seedlings, water and irrigation, fertilizers, mechanization and equipment, insecticides and pesticides, etc);

Labour inputs; and other topics relating to cost of production and other economic characteristics.

Coverage of the programme

80. Surveys for the collection of current statistical data on crop areas, yields and production are generally carried out on a nation-wide basis and the results are generally shown or published on a regional basis (e.g. by provinces or other administrative sub-divisions). For purposes or crop statistics, a supplementary and recommended sub-division would be that by agro-ecological zones. In such a case and, given the limited resources for agricultural statistics, the coverage of the survey can be limited in each agro-ecological zone to the major crops grown in it.

81. An as illustration, the distribution of national areas under specific crops in Cameroon, where the administrative sub-divisions into provinces approximate to agro-ecological zones, is given in Table 1.

Table 1. Percentages of the national area under specific crops located in each Province in Cameroon [19]

Crop	Province: North	East	Central South	Coast	West	North West	South West
Cotton	(97)[1/]	-	-	-	1	1	-
Cocoa	-	(9)	(62)	8	2	-	(18)
Coffee	-	7	(9)	(15)	(37)	(15)	(17)
Tobacco	(16)	(18)	(42)	-	(15)	9	-
Millet & sorghum	(97)	-	-	-	-	2	-
Maize	(10)	7	(22)	6	(27)	(21)	7
Cassava	8	(9)	(25)	(10)	(25)	(14)	8
Yam and cocoyam	1	5	(25)	8	(30)	(17)	(14)
Bananas and Plantain	1	6	(38)	8	(22)	(11)	(14)
Groundnuts	(33)	5	(20)	4	(26)	(9)	3
Beans	(46)	1	4	3	(28)	(16)	2

[1/] For the meaning of figures between brackets see next paragraph.

From the table, it can be seen that cotton, millet and sorghum are grown almost exclusively in the North; cocoa mostly in the Central South; beans and groundnuts mostly in the North and West while crops like maize, cassava, etc. are found in different proportions in all the provinces.

82. Crop coverage is to be as comprehensive as possible but not at the expense of the quality of the data. In developing countries, minor crops could be neglected if including them would overburden the survey and appreciably increase its cost. However, cash or export crops should not be favoured at the expense of auto-consumed food crops but some kind of balance, depending on the conditions of the country, should be established between cash and auto-consumed crops when organizing a crop survey. In some developing countries, where it was essential to use objective methods for the collection of the data, the practice was to limit the coverage to at most two or three of the most important cash crops and three to four of the most important auto-consumed crops in each of the regions. Obviously, the crops investigated differed from region to region. For example, the percentages of the crops to be investigated are given between brackets. However, provincial and national requirements for data will have to be met. The list of crops to be covered nationally or in provinces or districts will depend upon the national and provincial requirements as well as upon the importance of the crop in the external trade of the country. In any case, serious consideration for the need to use more expensive objective measurement techniques of area and yield should be given for the most important crops.

83. Since crop yields depend on the agricultural techniques, the inputs and the level of mechanization, the coverage of crop surveys should also be comprehensive but the data should be shown separately for each of the three sectors of agriculture, namely traditional, progressive and modern sectors of agriculture which are highly dependent upon agricultural techniques. Such a classification would be very useful specially in stratified sample surveys with different sampling fractions for the three sectors. However, no simple definition which would show the exact limits of the different sectors can be given. This depends on the

special conditions in each country. The following attempts have been made to define these sectors.

84. Farms in the modern sector (sometimes called estates, agricultural establishments or simply large farms) have to conform to certain recognized criteria. These criteria are based on:

- Size of the farm: above a certain fixed limit;
- Destination of the products: for sale;
- Labour inputs: use of paid permanent workers or work by cooperatives' members;
- Mechanization: use of important machinery and equipment;
- Organization: Book-keeping of records of activities, inputs and output.

85. Farms in the progressive sector conform to some of the above criteria but not all. They are of a moderately large size, they produce mainly for sale but some of the produce is for home consumption and some mechanization and modern agricultural techniques have been introduced in the operation of the farm.

86. Farms in the traditional sector are generally small in size, produce mainly for home consumption, do not employ, or only occasionally employ labour paid in kind or in cash and use simple agricultural implements.

87. From the above it can be seen that the definitions are rather vague and thus may be differently interpreted by the countries which quite often use only the dichotomy modern/traditional farming or commercial/subsistence farming.

88. For precision purposes, in the organization of sample surveys it would be very useful that the distinction between the different sectors defined above be done a priori and that they be considered as different domains of study with perhaps different questionnaire and different methods of collecting the data. It is recommended that at least the so-called modern sector, whatever be the definition used by the country, be identified, that a separate list of the farms belonging to it be established and that a larger sample (or the totality) of these farms be investigated.

89. The simplest crop area and yield survey is one in which the coverage in time is reduced to the single period of harvest when both the harvested area and the harvested yield are estimated or measured. When the survey programme covers several crops the harvesting period of which may vary in time, the statistical operations of estimating the crop area and yield will have to be repeated for each individual crop. They will have also to be repeated at each agricultural season within the year when successive cropping is practised.

90. Simple surveys in which the time coverage is limited to the time of harvest cannot meet the needs of development planning. No information is gathered either on the agricultural techniques, the inputs or on the times and frequency of their application, etc. Also, no data is collected on pest attacks and natural and other calamities, their severity, the period of their occurrence and the percentage of the crop damaged. Finally, no early warning or crop forecasting systems can be established.

91. For the above reasons, it is essential that the time coverage be almost continuous during the agricultural year. Thus the survey should be of the multi-round type with rounds starting at the time of preparation of the soil and ending with the processing and

disposal of the produce. The rounds could be periodic at regular intervals of time (fortnightly or monthly) or they could be spaced during the growing cycle of the crop according to its phenological characteristics. In the case of successive cropping, the same set of survey rounds should be repeated for each of the crops in the succession.

92. In conclusion, the area, yield and production surveys should form a part of an integrated system for the collection of food and agricultural statistics and provide links with the data needed for appropriate evaluation, analysis and use of the data. For this purpose there is need for thorough attention to related concepts, definitions, classifications and tabulations to ensure that the data are compatible and usable for development planning and socio-economic decision making.

Design of Crop Area and Yield Surveys

93. In designing a statistical survey, the aim should be to reduce, to the extent feasible under existing conditions and available resources, the over-all survey errors. To achieve this end, all sources of errors that affect survey results should be thoroughly examined and appropriate methods and procedures to reduce these errors should be devised for all aspects of the survey. The rational approach to survey design requires that due regard should be paid to the conditions of the country, such as its economic and social development, the available resources in men, money and material, the existence of transport and communication facilities, the level of training of the investigators and the attitude of the people. All this requires highly qualified personnel in sampling techniques and their application, a well equipped field organization and good relations with the people affected.

94. Much has been said and wirtten on the advantages and disadvantages of the use of sampling techniques versus complete enumeration in the taking of censuses of agriculture. However, the arguments used are not necessarily applicable to crop area and yield surveys. They could be applicable if the unit of enumeration, namely the crop area or production in individual fields or plots, is arrived at through the holding. Generally, most current agricultural statistics are independent of the holding and the data collected on the characteristics of the crops are:its area, yield and production broken down according to the type of area, yield and production, to the agricultural practices and operations involved and to the inputs. Some of the data can be estimated through direct observation of measuring while others will need to be secured through the interview with the farmer. There is need, however, to back such data with other information needed for compatible sets of data on food and agriculture. It is to be noted that presently planners are requesting more and more, that the data on crop areas and production, be cross-classified with the characteristics of the holdings and of the holders.

95. Survey designs for the collection of crop area and yield statistics vary widely: between countries according to the level of statistical development; within countries for the different sectors of agriculture (e.g. socialist and private, modern and traditional) and also according to the importance of the crop for the national economy. Thus, methods used in the same country can be as simple as eye estimation or mail survey or as complicated as measuring areas and yields.

96. The following crop estimating systems or surveys cover almost all the methods used at present for the estimation of the areas:

- Eye estimation of the crop area in localities or small sub-divisions of the country (crop reporting locality-wise)

- Use of cadastral maps and other ancillary information to arrive at a reasoned estimate

- Complete enumeration or a sample survey through a mailed questionnaire or reports from the holdings (crop reporting holding-wise)

- Complete enumeration of the holdings by enumerators and the interview of the holders

- Sample survey of holdings using the interview method and the declarations of the holders

- Sample survey using area, point of line sampling and observation of the crops in the sample

- Sample survey with objective measurements on a sample of fields.

97. Table 2 shows the distribution of the countries according to the method or methods used for the estimation of crop areas.

98. For the estimation of crop yields or production[1/], the methods utilized by the countries are:

- Eye estimation of the average yield or the total production in a locality or a small sub-division of the country

- Complete enumeration or a sample survey through a mailed questionnaire or reports from the producing units

- Complete enumeration (very rare) or a sample survey by enumerators and declaration of the holders

- Sample survey with objective measurements of the yield (crop-cutting for yield).

99. Table 3 shows the distribution of the countries according to the method or methods used, mainly in the decade 1970-1979, for the estimation of crop yields or production.

100. As can be seen from Tables 2 and 3, the system established and the practices used by countries to collect the data on crop areas, yields and production vary widely, not only between countries but also within the same country. More detailed information on the national systems and practices are given in the FAO publications "National Methods of Collecting Agricultural Statistics" and its Supplements [4], publications based on communications by the countries concerned to the FAO. Extracts from these publications are given in Annex I as illustrations. They cover the methods used for the collection and estimation of crop area, yields and production in the following countries: Belgium, Brazil, Bulgaria, Canada, Egypt, Nigeria, Yugoslavia.

1/ Some countries collect statistical information on the production and then calculate the yield.

Table 2. Method of Estimation of Crop Areas by Countries[1/]

Region	Reporting		Enumeration by Interview		Measurements
	Locality-wise	Holding-wise	Complete	Sample	
Western Europe and North America	Greece Italy Spain United States	Canada Denmark Finland United Kingdom United States	Austria Belgium Germany, Fed.R. Ireland Israel Luxembourg Malta Netherlands Sweden	Cyprus France Norway Portugal Germany,Fed.R.	France United States
East Europe	Czechos-lovakia Poland	Bulgaria Czekoslovakia Hungary Poland U.S.S.R.	Poland		Bulgaria
Asia and Far East	India Indonesia Kampuchea Korea, Rep. of Laos Malaysia Thailand Viet Nam	Australia Burma		Australia India Japan Malaysia Philippines Sri Lanka Thailand Viet Nam	India Japan Korea, Rep. of Malaysia Nepal Thailand
Africa	Algeria Chad Congo Ethiopia Mauritius Senegal Swaziland Tanzania Togo Zaire	Algeria Swaziland		Benin Botswana C.A.R. Chad Ghana Guinea Ivory Coast Kenya Liberia Malawi Morocco Nigeria Zaire	Botswana Chad Ethiopia Ghana Guinea Ivory Coast Kenya Lesotho Liberia Malawi Nigeria Togo Uganda Zaire

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1/ This table is based on the FAO publication: National Methods of Collecting Agricultural Statistics [4] and its Supplements.

Table 2 (Cont.d)

Region	Reporting		Enumeration by Interview		Measurements
	Locality-wise	Holding-wise	Complete	Sample	
Latin America	Argentina Bolivia Brazil Dominican Rep. Ecuador Guyana Haiti Jamaica Mexico Trinidad & Tobago Uruguay Venezuela	Colombia	Venezuela	Bolivia Brazil Chile Colombia El Salvador Guatemala Nicaragua Panama Paraguay Peru Puerto Rico Venezuela	Bolivia
Near East	Afghanistan Jordan Lebanon Libya Pakistan Qatar Sudan Syria		Egypt	Bahrain Cyprus Iraq Jordan Lebanon Saudi Arabia	Egypt Iraq Jordan Pakistan Saudi Arabia Sudan Syria

Table 3. Method of Estimation of Crop Yields and Production Distribution of Countries 1/

Region	Eye Estimation Locality-wise	Reporting (Holding by mail)	Enumeration by Interview		Measurements
			Complete	Sample	
Western Europe and North America	Austria Belgium France Germany, F.R. Greece Italy Luxembourg Netherlands Norway Spain United Kingdom United States Yugoslavia	Canada Portugal	Malta	Denmark Finland Ireland United States	France Germany, F.R. Sweden United Kingdom United States

Table 3. (Cont.d)

Region	Eye Estimation Locality-wise	Reporting (Holding by mail)	Enumeration by Interview		Measurements
			Complete	Sample	
East Europe	Bulgaria Czechoslovakia	Czechoslovakia Hungary Poland U.S.S.R.		Poland	
Asia and Far East	India Indonesia Japan Kampuchea Laos Viet Nam	Australia Burma		India Japan	Burma India Indonesia Japan Kampuchea Korea, Rep. of Laos Malaysia Nepal Philippines Sri Lanka Thailand Viet Nam
Africa	Algeria Chad Congo Ethiopia Kenya Mauritius Senegal Swaziland Tanzania Togo Zaire	Algeria Swaziland		Benin Botswana C.A.R. Ghana Guinea Morocco Nigeria Zaire	Algeria Botswana Chad Ghana Guinea Ivory Coast Lesotho Liberia Morocco Nigeria Togo Uganda Zaire
Latin America	Argentina Bolivia Brazil Dominican Rep. Ecuador Guyana Haiti Jamaica Mexico Trinidad & Tobago Uruguay Venezuela	Colombia		Bolivia Brazil Chile Colombia El Salvador Guatemala Nicaragua Panama Paraguay Peru Puerto Rico Venezuela	Bolivia

Table 3. (Cont.d)

Region	Eye Estimation Locality-wise	Reporting (Holding by mail)	Enumeration by Interview		Measurements
			Complete	Sample	
Near East	Afghanistan Egypt Jordan Lebanon Libya Pakistan Qatar Sudan Syria			Bahrain Cyprus Iraq Jordan Saudi Arabia	Egypt Iraq Jordan Pakistan Sudan

1/ This table is based on the FAO publication: National Methods of Collecting Agricultural Statistica [4] and its Supplements.

Locality-wise system of crop reporting

101. Low-cost surveys of crop areas, yields and production are those designed on the bases of both eye or judgement estimation of the variables for small administrative units and of regular reporting. Almost all statistically developed countries have used and many countries (developed and less developed) are still using a system of crop reporting for the collection of current agricultural statistics. For this reason, it might be advantageous to countries in the early stages of statistical development not to embark on large-scale more accurate surveys which require considerable resources, but to use this approach (in spite of the fact that the data may contain some inaccuracies) and to supplement it gradually with sample surveys using objective measurement, where necessary, in the case of the most important crops.

102. Crop reporting locality-wise systems are generally based on the use of:

- localities, villages, communes, etc. as the unit of enumeration
- complete enumeration of these units (all localities, etc. are covered)
- extension workers, village chiefs, commissions, voluntary farmers, etc. as investigators or reporters
- eye and judgement estimation of the crop areas
- regular reporting of the crop conditions
- eye and judgement estimation of the crop yields
- manual processing of the data at the regional level.

103. The crop reporting system has many advantages which makes it very attractive. The main advantages are:

- its low cost
- the simplicity of the data collection
- the data is collected for small area units which could be aggregated easily
- the collection and processing of the data is simple (mere summation)
- the timeliness of the information may be easily ensured.

While the main disadvantage is that, the method being subjective, there is no way to evaluate the quality of the data which could be inaccurate and biased. In any case, this method is suitable in some countries for the less important crops.

104. In view of the advantages mentioned above, various attempts have been made to improve the accuracy of the data collected. The survey design and organization were so planned as to eliminate some of the biases. Mapping material was prepared and distributed to the reporters and served to reduce inaccuracies in eye estimation of areas. The reporters were provided with ancillary information on crop behaviour in previous years which helped reduce errors in the estimation of yields and production.

105. The first operation in organizing a crop reporting system is the sub-division of the agricultural land in the country into administrative sub-divisions and/or agro-economic zones and the preparation of the corresponding mapping material in which the land use categories and the main crops would be indicated. The total area of the zone would then be sub-divided into a number of enumeration or reporting units. These could be area segments, localities, villages or small administrative units like communes, etc. One or more of the enumeration units would be allotted to one investigator or reporter.

106. When the total area of the unit, the total area of the arable land and/or the total area under permanent crops are known, eye estimation of crop areas gives somewhat more reliable results. The problem of estimating crop areas reduced to the sub-division of the total into components and allocating each component to the corresponding crop. Errors and biases in this conditional allocation of crop areas are generally much smaller than in the case where the total area is not known.

107. Besides the data on land use categories, crop land, etc., it is very useful that the reporter be provided with ancillary information, previously collected, concerning the main agricultural characteristics of the unit of enumeration. Some of these characteristics which might help to improve the quality of the estimation are the following:

- number of farmers and/or of persons economically active in agriculture
- agricultural practices
- calendar of the agricultural operations
- average crop yields
- potentiality of irrigation
- amounts of improved seeds distributed or sold
- amounts of fertilizers, pesticides, etc. distributed or sold.

Much of this ancillary information could be gathered from village chiefs or other administrative officers.

108. Subjective estimation of crop areas and yields can only be reliable when it is carried out by specialized agricultural personnel with wide experience in the subject. Estimation by newly trained enumerators, even when they are highly qualified, has proved to be disappointing at least during the first few years of service. For this reason, it is recommended that the operation of estimating crop areas and yields be left to or controlled by either long-standing agronomists and extension workers or by specialized commissions composed of village or locality chiefs and a number of other knowledgeable farmers of the enumeration unit. However, in both cases, biases of a certain type may be introduced: extension workers may tend to over-estimate areas or yields on the assumption that the technical assistance they give to the farmers must have improved the results, while farmers in commissions will tend to under-estimate areas or yields in order to show that farmers' conditions are not improving much.

109. Regular reporting is the main feature of this type of crop survey. The reported information could be qualitative or quantative. Qualitative information is either given in absolute terms, e.g. the wheat yield is expected to be: very good, good, normal, bad, very bad, or it is given in relative terms in comparison with some benchmark, e.g. the sown area is: much larger, larger, equal, smaller, much smaller than the area sown the previous year. Similarly, the quantitative information is either given in absolute terms, e.g. the area under cotton is 20,000 hectares or given in relative terms (percentages), e.g. the damaged area is about 20% of the total area. Qualitative information, in absolute or relative terms, can be useful for an early warning system or for crop forecasting especially if, after proper study, some numerical point system is devised to translate the qualitative terms into quantitative ones.

110. How much statistical detail the reports should contain will depend on the type of crop; the number and frequency of the reports during the agricultural year and on the need

for and degree of accuracy of the data. If the reports are quite frequent (fortnightly or monthly), it is necessary, for the major crops, to report on the changes which occurred during the inter-rounds period, e.g. new sowing or plantings, areas damaged or abandoned, areas harvested, growing conditions of the crop, agricultural operations carried out, new inputs applied, yields of harvested crop and disposal of the production. When the reports are less frequent (annual or quarterly), it might be necessary to record at one single time all the data planned to be collected. For minor crops, it might be sufficient to limit the statistical data in the reports to the most essential characteristics of the area and the yield: gross area sown, net area harvested and yield corresponding to each of the cases: no special inputs, irrigated, fertilized, with improved seeds and applicable combinations thereof.

111. If statistics of crop areas and yields are to serve as an early warning in cases of crop failures due to pest attacks, natural calamities, etc., and also to help the authorities formulate and implement import, export, storage and distribution policies, it is essential that a time-table of reporting should be programmed well in advance and that the reporters should strictly adhere to it. Moreover, the reports should contain all the elements on which crop forecasting can be based. These include the growing conditions and state of health of the crop, comparisons with previous years results, the reporters' own subjective estimates of the expected yield or production, etc.

112. The statistical schedules to be used for recording the data can be individual-crop or multiple-crop forms. In the former case, for each crop there will be one particular schedule on which will be recorded the data successively at each round while, in the latter case, one schedule will be used at each round and on it will be recorded the data corresponding to all the crops investigated at that particular point of time. In both cases, the headings of the columns in the schedule can be the same: types of areas, agricultural operations, inputs, yields and disposal of the production, while the rows will be filled differently: dates of the rounds and the data for one crop at those dates in the individual-crop form or names of the crops and the data on all the crops for that particular round in the case of multiple-crop form.

113. One advantage of the individual-crop schedule is that it shows at one glance the whole history of the crop and its evolution in time and up to date. Another advantage is that the headings of the columns can be particularized and only those characteristics relevant to that crop are included. Furthermore, the collation and processing of the data, either manual or mechanical, are reduced to simple summation. The main disadvantage is that it necessitates as many forms as there are crops in the survey and that the reporter has to send to the statistical office an up-to-date crop of all the forms at each reporting time.

114. As against this, the advantage of the multiple-crop schedule is that, at each round, only one form is to be filled by the reporter and sent to the statistical office which could check the data for inconsistencies, extraordinary deviations, etc. between the different rounds and send it back to the field staff for revision and correction. In order to get the historical behaviour of a crop, the data on such a crop could be transcribed from the different multiple-crop schedules to an individual-crop form; however, this operation takes time and a further disadvantage is that errors in course of transcription may be introduced. Perhaps for the most important crops individual crop forms may better be used while a multi-crop form is used for the remaining crops.

115. In the organization of a crop reporting locality-wise system, it may be recommended that the field staff prepare the reports or more precisely the statistical schedules in triplicate. The first copy is to be kept by the reporter as a reference in order to avoid gross errors and inconsistencies between the successive reports and also, if the individual-crop form is used, to add on it successively the data at each round. The second copy is to be communicated to the regional statistical office for checking, collating and manual processing. Moreover, the processed data can serve the authorities to plan better regional development programmes. The third copy, together with the processed data at the regional level, is to be sent to the central statistical office for reviewing, processing, analysis and publication of the statistical information.

Holding-wise direct crop reporting system

116. Another comparatively low-cost survey design for the collection of crop area and yield statistics is based on the method of "self-enumeration". The questionnaires or schedules are generally sent by mail to the holders who fill in the requested information and send them back to the statistical office. A somewhat similar system is used in some countries (especially those with centrally planned economies), in this case each producing unit has to report regularly on its activities, on the condition of the crops and on the expected yields and other details.

117. The self-enumeration method can only be used with a certain category of holders. They have to be

- literate
- able and willing to respond
- with experience in replying to statistical inquiries
- interested and involved in a continuous study of their respective farm activities
- keeping records.

For this reason, self-enumeration is being used in some statistically developed countries and also for the modern sector of agriculture in some less statistically developed countries.

118. Even then, the rate of response is not very high and reminders have to be sent to the holders (in Australia, three sets of reminders are sent to the holders at suitable intervals). In Canada, where large-scale surveys are conducted by mail with response being on a strictly voluntary basis, the rate of response runs from 15 to 20 per cent of total mail out and, in smaller scale panel (selected correspondents) surveys, the response rate runs about 60-70 per cent. In certain countries it is necessary to send statistical enumerators to visit non-respondents or call them by phone.

119. If the information on crop statistics is requested through a self-enumeration procedure, the questionnaires are bound to be more elaborate. First of all they have to provide the respondents with an explanation of terms and concepts used. Sometimes, it will be necessary to reproduce long definitions in order to avoid confusion on the part of the respondents. Afterwards examples are also provided in order to help readers to visualize better what is meant by several questions. Then follow indications regarding the units that have to be used to express the replies. Other instructions (e.g. on coding) may also be added whenever found convenient.

...

120. When the prerequisites mentioned on self enumeration (para. 117) are satisfied, the mail questionnaire procedure has the advantage that the cost of the survey in respect of the collection of the data is reduced to the overhead cost, the printing of the schedules and the cost of postage and follow-up for non-response. Moreover, the quality of the statistical information is of a high level since the data on areas, farm activities and operations, inputs and output, etc. are all known to, measured and recorded by the respondent. Unfortunately, in developing countries where literacy rate is not high and statistical consciousness is not necessarily developed, this method cannot be used except perhaps for enumerating the holding in the modern or the socialist sector of agriculture (for the type of questionnaire to be used cf. para. 157).

Complete enumeration of holdings

121. Yearly or more frequent complete enumeration of holdings to collect by interview crop area and yield statistics is a huge task which may require the use of thousands of enumerators working full time (about one man-year per 500 holdings), especially in those countries where the number of holdings exceed the million (25 such countries exist). Moreover, if the enumerators work part-time, seasonally or occasionally, multiples of the number of full-time enumerators would be needed. For example, in Germany,Fed.Rep. (4), the number of crop-growing holdings is about 1 500 000 and, in order to get data on crop areas and yields, the statistical office utilizes, besides the regular enumerators, the voluntary services of four different groups of specialized reporters: 7 500 reporters for cereals, 2 400 reporters for vegetables, 5 800 reporters for fruits and 1 400 reporters for vines.

122. In order to reduce the amount of statistical work, in some countries the complete enumeration of holdings is not carried out yearly but every 3-4 years. In the intervening years the changes in crop areas are introduced by special commissions, through observation and eye estimates or sometimes a sample survey is carried out to determine the crop areas. In others, district officers request farm operators to attend on "session days" a meeting during which the district officers assisted by temporarily employed enumerators fill in the statistical schedules.

123. Like the crop reporting system on the basis of localities, complete enumeration of holdings has the advantage that the data can be made available for small administrative or agro-econological sub-divisions of the countries and thus serve as a basis for regional planning. However, it requires the establishment of a vast field organization to cover the whole country without omission or duplication; the employment of enumerators able to understand the various definitions and instructions, and it is very costly: large sums of money are needed for the survey material, the payment of the staff and for processing the returns of the survey.

124. Other possible prerequisites for the establishment of such a complete enumeration of holdings system for the collection of crop statistics are:

- the existence or preparation of up-to-date farm registers,
- the existence of up-to-date large-scale maps or aerial photographs,
- a complete list of enumeration districts along with their broad characteristics and maybe sketch maps,
- the existence of a detailed land cadastre,
- the ability and willingness of the holders to supply the needed information,
- a large number of qualified and well trained enumerators.

In most developing countries, most of these prerequisites are lacking and complete enumeration of holdings may not be feasible.

Sample surveys

125. Many manuals and handbooks have been published on the use of sampling techniques to collect statistical information and on the general aspects of the organization of sample surveys. In this section, the discussion is limited to a review of those practical issues relevant to the collection of data on crop areas, yields and production. The review covers: frames and statistical units, sampling design, periodicity of collection and time coverage.

126. For a global study of crop areas and yields, the universe under consideration is the agricultural land, or more precisely the crop land (arable land and land under permanent crops) in the country. When the study is limited to one or a few crops, the universe consists of all the fields on which this or these crops are grown. Ideally, the elementary unit of enumeration for production estimation is the plant or tree. However, this unit is rarely used. For practical reasons and for area and yield statistics, the field or plot on which the crop is grown which usually represents a cluster of elementary units is used as the unit of enumeration. The main characteristics of the crop are: the different types of area and yield, the agricultural techniques applied and the inputs. In the case of trees their number, age and sometimes other properties, including average yield per tree of bearing age, are additional important characteristics.

127. For a proper study, utilizing complete enumeration or sampling techniques, a complete list (the frame) of all the individual enumeration units or a list (frame) of different units through which all the enumeration units could be identified, should be available. This is very rarely the case for, even when the list is established immediately after a complete enumeration census of agriculture, changes may occur between the time the list is prepared (or up-dated) and the time when the inquiry is carried out. Also very often the universe is truncated on purpose, leaving out what is considered to be a negligible fraction, e.g. when a minimum size is fixed for holdings. In such a case, the results of the survey relate to the domain of study (the truncated part) and not to the whole universe.

128. For one-stage or multi-stage sampling surveys, the universe (or alternatively the domain of study) is sub-divided into a number of separate, well defined and clearly identifiable parts or segments which serve as primary sampling units and the frame at that stage is the list of these units or segments together with some of their characteristics. For the sub-division to be valid and the frame to be complete and accurate, every enumeration unit must belong to one, and only one, of these primary sampling units. This implies that the aggregate of primary units covers all the members of the universe and that the boundaries of these segments are defined without ambiguity so that an individual member of the universe cannot belong to two different primary units. Another useful condition is that the primary units should not miss the boudaries of domains of study for which separate statistics are required. For example, if separate information is required on the modern and traditional sectors of agriculture, it is better to separate them right at the beginning into two different domains of study and sub-divide them separately into primary units. A primary sampling unit may be identical with the enumeration unit in the case of one-stage sampling but this need not necessarily be so as cluster sampling may be used.

129. A sample of these primary units is then selected and each primary unit can be:

1. investigated on a complete enumeration basis (one-stage sampling or cluster sampling); or
2. considered as a separate domain and for each primary unit selected a frame (or list) of the elementary units is prepared and a sample of elementary units is selected (two-stage sampling); or
3. considered as a separate domain and sub-divided into a number of parts, each part being a group or cluster of elementary units which will be considered as secondary (second stage) sampling units for the purpose of a third stage sampling, and so on. It is to be noted that, at each stage of sub-division of a sampling unit into smaller sampling units, every elementary unit of the larger sampling unit must belong to one and only one of the smaller sampling units.

130. Two types of material are usually available for the construction of frames at the primary sampling stage:

1. Enumeration areas constructed for the census of population and/or for the census of agriculture. They are generally accompanied by sketch maps showing their boundaries and also by a number of qualitative or quantitative characteristics which permit their stratification into homogeneous groups of elementary units.
2. Administrative units: small sub-divisions of the country for government administrative purposes, e.g. villages. These units generally consist of an aggregate of individual persons, holdings or households under one single administrative jurisdiction. They are also generally accompanied by some characteristics like size, number of holdings, etc., which help in their stratification.

131. The first type of units (area units) are more stable in time and, if their boundaries are well defined and recognizable on the ground and the frame is complete, i.e. covers entirely the universe or the domain of study, then any newly created elementary unit can be assigned without ambiguity to one or the other of the primary units. However, area units are difficult to construct, especially in developing countries where recognizable boundaries can only be found for very large areas. Also the ancillary information required for their stratification is not, in general, readily available. However, the situation is improving as a result of recent technological advances in remote sensing and the use of area frames should be given serious consideration where practicable.

132. The administrative village as a primary sampling unit has been used so far more often than area units during the last decade in a large number of developing countries. For, in many developing countries, it was found that the construction of a frame of area units was not practicable while lists of administrative villages almost always existed and were revised periodically. However, a frame of villages is not very stable: new hamlets may spring up in the vicinity of a village or in far-away places which do not belong to any already existing administrative village; villages may be abandoned altogether or shifted elsewhere; villages may be split into two or more villages or a number of hamlets or villages may be consolidated into one village. In fact, an examination of the lists of villages used in the past often showed that they were not reasonably free from defects such as inaccuracy, incompleteness, duplication, etc. Furthermore, in some African and other countries, the concept of a village may not apply to a large segment of the population and a suitable alternative

administrative sub-division may have to be used.

133. Frames of villages can be checked by sending out questionnaires to administrative officers and/or sending teams of special investigators who would tour the country systematically, division by division, and ascertain, with the help of the local authorities or other knowledgeable persons and of available information, the completeness and accuracy of the list. The investigators can also collect ancillary information on each of the villages in the course of their visits. This operation might be a costly and time-consuming operation; however, it is essential that it be carried out if frames are to be complete and accurate.

134. Some countries have recently introduced in their statistical system a Locality Data File or Community Statistics File which they keep up-to-date. The file covers every locality (or village or smallest administrative unit) of the country and it contains a large number of sets of data on different aspects of the structure and on the socio-economic characteristics of each of the localities. Whenever such an up-dated file exists, it provides an accurate and complete frame for the localities as primary units. Moreover, for stratification purposes, one could select from the whole range of data contained in the file those agricultural characteristics most suitable for the objectives of the sample survey to be carried out.

135. The secondary sampling units could be the ultimate (or elementary) units or they could be intermediate units. Thus, they could be individual crop fields or agricultural holders, etc. Generally, no ready-made lists of secondary units exist and the listing and enumeration of these units is to be carried out for each selected (sample) primary unit. The preparation of a complete list of fields or holdings in a village is not easy. Lists prepared even by the village chiefs were found to be seriously incomplete. Listing of fields or holdings by "dwelling-to-dwelling" enumeration is an arduous and costly operation; however, it might be the only way to prepare a satisfactory frame in a number of developing countries.

136. The process of preparing complete and accurate lists and enumerating the units is to be carried out at every stage of sampling. It is recommended to collect, during the enumeration stages, some relevant qualitative or quantitative information on the characteristics of the unit in order to improve the efficiency of sampling.

137. The main objective of selecting an appropriate sample design is to optimize the precision of the estimate of required data, taking into account the general socio-economic conditions in a country and of the available resources for the enquiry. Thus, the sample design will depend mainly on:

- the dispersion in space (throughout the domain of study or the country) of the units to be enumerated
- the level of administrative or other divisions of the country for which separate data are required
- the degree of variability of the characteristics of the units under study
- the degree of precision of the estimate of the required data
- the techniques of enumeration to be used
- the cost of collecting the data
- the available budget.

138. When a complete and accurate frame of enumeration units is available, e.g. an up-to-date register of agricultural holdings, a one-stage sampling design could be very efficient and the estimates made from such a sample are generally more precise than estimates obtained from a multi-stage sample of the same size. However, given the large dispersion of the units over the country (or domain of study), the cost of collecting the data by interview is much larger than in a multi-stage design where the primary units are compact areas of which only a sample is to be investigated.

139. The sampling units can be selected from the list in either a random or a systematic way. The two methods of selection are almost equivalent when the elementary units are listed in a random way, but the systematic selection has the advantage of being easier to carry out. Moreover, the precision of the estimates can be improved if, in the case of systematic selection, the elementary units are re-ordered or re-arranged before the selection according to some important characteristic known to be positively correlated with crop areas and/or yields.

140. A type of one-stage sampling is the cluster (or area) sampling where the universe is divided into a number of primary units, each one of them being a group or cluster of elementary units. A sample of clusters is then selected and all the elementary units within the cluster are investigated. This is the case when fields are the elementary units, an area segment being the primary unit or cluster and all the fields belonging to the segment are investigated. The collection of the data through such a design is much less costly than the collection in simple random sampling of fields but the precision of the estimates is much lower for the same size of sample. The precision of the results would be better if the elementary units in the cluster were highly heterogeneous which generally is not the case in crop surveys.

141. In many situations, multi-stage sampling is unavoidable due to the difficulty of preparing lists of elementary units not only for the universe but very often also within the primary sampling units. However, the precision of the results decreases with the introduction of new stages in the sampling design and with every new stage a new addition to the variance of the estimate is introduced. The size of this increase in the variance depends naturally on the degree of variability of the sampling units at that particular stage. Thus, it is recommended not to increase the number of sampling stages and to limit them preferably to two or three stages.

142. Very often the universe is sub-divided into strata (sub-populations) such as administrative or geographic sub-divisions, branches of the economy, sub-divisions of the universe by size or other characteristics of the elementary units, etc. Strata are then considered as separate universes and they are sampled separately using the same or different sampling designs. Sometimes, one or more strata are investigated on complete enumeration basis, while, for the investigation of the others, samples are drawn, e.g. modern, progressive and traditional holdings. In general, stratification increases the precision of the results. For a greater precision, stratification should be made in such a way as to maximize the variability between the strata and minimize the variability of the elementary units within each stratum. Allocation of the elementary units to the wrong stratum (stratum to which they do not belong) may cancel all the advantages of stratification and, moreover, if the wrong allocation of the units is accompanied by different sampling fractions in the different strata, the precision of the results may be lower than in simple random sampling.

143. In probability sampling, to each elementary unit is attached the probability of its selection in the sample. This probability may be uniform, i.e., each elementary unit has the same probability of being selected (probability equal to the sampling fraction) or to each unit is attached, a priori, a specific probability on the basis of some prior knowledge of its importance or size. The selection of the sample units with probability proportional to some measure of the size of the unit may be very useful in increasing the precision of the results; however, if wrong probabilities are attached to the units, the precision of the estimates might suffer. Also, since the study covers many characteristics of the units, a set of which may be positively correlated, another set uncorrelated and a third set negatively correlated with the size of the unit, using selection with probability proportion to some measure of size may improve the precision of the data on the first set of characteristics, keep stationary the precision of the second set and decrease the precision of the third group.

144. Since agricultural operations are highly variable over time during the year, the period of survey operations is generally a complete agricultural year. In some cases, the survey operations are carried out continuously throughout the year; thus, the enumerator observes and records data on a certain number of units during a certain period of time, then he moves on to a similar group of units and repeats the operations and so on. He might repeat the survey operations on the same units after a certain interval of time (e.g. once every quarter or semester). In other cases, the survey operations are carried out at a small number of fixed points or periods of time during the year. For the latter procedure, the sample time unit assumes importance and failure to ensure representativeness in the time dimension may give biased results. Thus, if the survey is carried out through the enumeration of holdings and the operation is due only once or maybe twice during the agricultural year, it is necessary to resort to retrospective questions with the risk of reducing the accuracy of the information, due to memory lapses of the respondents.

145. The time-reference period, i.e. the period of time to which the data refer, depends on the information to be collected. For certain items it could be a point of time (e.g. at harvest, area harvested), for others it may cover a whole agricultural season, (e.g. amount of fertilizers used on the crop) or a year (e.g. total production). On the other hand, the time-reference period should not be too far removed from the reporting time in order not to strain respondents' memories and to improve the accuracy of the data collected.

146. When a crop area survey is based on the observation or the measurement of the area under the crop at one or more points of time (random or at regular intervals) during the agricultural year, it might happen that, in some fields, the crop had not yet been planted or alternatively the crop had been already harvested and the corresponding areas are not measured or observed. In either case, the estimation of the crop area is under-estimated and it has to be corrected since the time reference period is the whole agricultural year.

147. In order to collect information on crop areas, yields and production countries have used different types of sampling surveys. The surveys varied widely in scope: from the general agricultural survey covering number of farms and their structural characteristics, crop areas and production, livestock, poultry and animal production, farm labour, etc. to the very specialized surveys which dealt with only one crop and sometimes only its yield. The surveys also varied in coverage: some covered all sectors of agriculture while others were limited to the so-called modern sector or to the socialist sector. Furthermore, techniques of enumeration, sampling schemes, periodicity of collection and time coverage differ widely from one country to another and from one survey to another.

148. Illustrative summary reports of national surveys with components related to crop areas, yields and production are given as Annex 2. These reports are based on communications by the countries concerned to the United Nations /11/. These reports are the following:

2A Survey of agriculture in COLOMBIA
$2B_1$ Survey of land utilization in FRANCE
$2B_2$ Cereals survey in FRANCE
2C Crop estimation surveys in the states in INDIA
2D Pilot study of crop-cutting of dates in SAUDI ARABIA
2E Pilot studies for the crop estimation survey in SUDAN
2F June survey of crop acreages and livestock numbers in USA

The inclusion of a summary report of a survey in Annex 2 does not necessarily imply the endorsement of the sampling design, nor the method used for field enumeration, nor any other aspect of the survey.

149. Annex 3 contains a long abstract from a paper by P. Delorme, first published in STATECO Bulletin de Liaison INSEE, Paris 1977 and reproduced by the FAO Statistics Division. The purpose of the paper is to "rehabilitate" the indirect assessment methods 'eye estimates, expert opinions, etc.) for current agricultural statistics in developing countries and to draw attention to some principles which could improve the quality of these methods. The inclusion of this Annex is not in any way intended to distract from the importance of using objective measurement techniques in the case of important crops for which more precise and timely estimates are needed.

Questionnaires and Schedules

150. The terms questionnaire and schedule have been indifferently used to represent the form on which is recorded the statistical information collected through an inquiry or a survey. In general, a questionnaire is a formal list of questions which are put without any deviation to a respondent and the main responsibility for supplying the correct answers lies with the respondent but the questions may be asked by an interviewer. A schedule is usually a blank form to be filled up by the insertion of particulars under the several headings, the responsibility of filling in the right information could be that of the respondent, but is, more generally, that of the enumerator. In practice, a questionnaire may include a schedule in some of its parts and vice-versa and hence the distinction between the two terms may not necessarily be important.

151. The format of the questionnaires or schedules depends on the method used for the collection of crop area and yield statistics. The format of the schedule used for locality-wise crop reporting is necessarily different from the mail questionnaire used in holding-wise crop reporting. The questionnaires or schedules used in a sample survey differ widely when the sampling scheme is based on area sampling or on sampling of holdings. Also questionnaires or schedules used for the interview method are different from those used when measurement of areas and yields is involved.

152. It is useful that the schedule for locality-wise crop-reporting includes the following information of general interest:

- identification of the locality (village, administrative sub-division, etc.),
- agricultural characteristics of the locality,
- general socio-economic information, and
- total physical area and its sub-division into land use categories.

The main contents of the schedule will depend on the objectives of the survey and should cover in more or less detail those topics mentioned under the section entitled "Components of a Programme for Crop Statistics" (para.79-92) which are of interest to the country.

153. The mail questionnaire to be used in holding-wise crop-reporting should be self-explanatory and, if it is considered necessary, should contain: definitions, instructions, footnotes, etc. to enable the respondent to interpret properly each question and reply accordingly. Besides the main topics on crop areas and yields, agricultural operations, inputs, etc., it might be useful that the questionnaire cover also general information on the holding structure and on the characteristics of the household associated with it. In such a case, data on crop areas and yields could be usefully cross-tabulated with the characteristics of the holding or the household.

154. The same procedure of enlarging the scope of the crop area and yield survey through the introduction of topics on the characteristics of the holding can be applied whenever the survey is carried out through interview of the holders. The supplementary topics could be few in number or the survey can be transformed into a yearly "census" of agriculture.

155. In sample surveys it might be useful to record on the schedules some of the information relating to the sampling scheme, e.g. method of selection of the sample, especially if it is the enumerator who does it, the sampling fraction or alternatively the expansion factor at each stage, in order to facilitate manual processing at the regional level. In area sampling and when the survey is carried out through observation, estimation or measurement of the parcels, fields or plots and with no contact with the farmers, the schedules can only contain a very limited amount of information.

156. When areas are measured or when crop-cutting for yield is applied, a special schedule is to be used for each field and for each of these operations. The schedule for area measurement should contain, besides the regular information on the crop or crops in the field, an empty space to be used by the enumerator for a rough free hand sketch of the field and in tabular form the names of the sides of the field, their length, the horizontal angle they make with the north and, in the case of abrupt slopes, the vertical slope angle. In the crop-cutting for yield schedule, besides the regular information on the crop, information on the following topics is needed:

- method of selecting the crop-cutting plot (including eventually the random numbers utilized)
- the size of the plot
- the density of the plants (in the field or within the plot)
- the weight of the produce as harvested
- the weight of the produce after processing (cleaned, threshed, winnowed, dehusked, shelled, etc.) and dried (the moisture content brought to a standard level).

157. In Annex 4, a set of questionnaires and schedules is given for illustrative purposes. Some of these have been actually used by countries for the collection of crop area and yield statistics. Others have been presented in different training centres sponsored by the FAO. They are:

4A	BENIN	Rapport Mensuel sur le Developpement de la Campagne Agricole
4B	FAO	Proposed Crop Reporting Form
4C	FAO	Schedules for: List of Parcels and Fields Field Questionnaire Crop Densities Questionnaire Crop Yield Questionnaire
4C	FRANCE	Utilisation du Sol au Cours de la Campagne Agricole
4E	U.S.D.A.	Farm Report : Acreage and Production of Grain Crops

Pre-test or Pilot Surveys

158. In countries with little experience in survey work and particularly in those where new types of surveys are to be introduced, pre-testing is of vital importance. Cases are known where a survey has completely failed because the preparations were not properly done. Pre-testing is not an exclusive feature of censuses, it is to be used in designing any type of surveys. However, in this section the discussion on pre-testing will be limited to the surveys for the collection of statistics on crop areas, yields and production.

159. Pre-tests or pilot surveys differ widely in scope, design, size of operation, etc. There are pilot surveys which deal with a small number of problems or even one single problem, e.g. testing the questionnaire to get information about the difficulties that might arise. On the other extreme, a whole series of pilot surveys is undertaken: the first pilot survey may be designed for collecting information about the feasibility of the main survey; subsequent pilot surveys might be organized for checking the validity of concepts, methods, estimates of costs, etc. Moreover, it is useful to point out that, in the case of existing surveys like those undertaken for the collection of current agricultural statistics, each such survey can also be utilized in designing subsequent surveys in addition to other pilot enquiries.

160. Since the systems proposed earlier for the collection of crop statistics vary widely from crop reporting to objective measurements of areas and yields and since composite systems combining different techniques could be and are used for different sectors of agriculture or for different crops within the same country, it is essential that, before embarking on a new system of surveys, countries undertake pilot surveys to test the validity and comparative merits of the different systems under their specific conditions.

161. Unlike regular sampling surveys, pilot surveys need not be based on probability sampling. On the contrary, the choice of regions, areas, holdings or other units to be investigated, should be purposive using available knowledge and representing various conditions. Generally, the selection of the units should be made in such a way as to reveal the difficulties that might arise and the problems that have to be faced. When one of the objectives of the pilot survey is to evaluate variables like time spent, work load, cost, etc., it is essential to

investigate not only average units with respect to various characteristics but also extreme cases (e.g. far-away as well as near-by, highly developed and under-developed) as well as other special cases.

162. The main objectives or scope of pilot surveys for the establishment of a system for the collection of crop statistics are the following:

- testing the adequacy of the methods (eye estimation, self-enumeration, interview, measurements)
- testing the questionnaires, schedules and instruction manuals
- evaluating abilities of the reporters, enumerators, etc. (e.g. understanding and ability)
- evaluating reactions and other related characteristics of the respondents (e.g. knowledge and willingness)
- study the variability of crop areas and yields between and within regions and over time with the agricultural year in order to improve the sampling scheme
- study of the quality of the frame: maps, aerial photographs, lists (e.g. completeness and accuracy)
- study of the quality of the measuring equipment (e.g. accuracy, cost)
- study of the time needed for the different survey operations
- study of the relative merits of manual and mechanical processing
- evaluation of the cost of the different survey operations.

163. When a system of locality-wise crop reporting is to be established, it would be useful to conduct a pilot study of the quality of the data under different conditions. For the estimation of crop areas the conditions could be:

- eye-estimates of the areas
- knowledge of the total area and its sub-division into land use categories
- knowledge of the crop areas which were cultivated the previous year(s)
- consultations with agricultural experts in the area
- consultations with agricultural producers in the area
- estimation by a local commission of "knowledgeable or informed persons"

or a combination of a number of these cases. While for the estimation of crop yields the conditions could be:

- eye-estimation of the crop yields based on observation of the crop condition
- knowledge of the previous year(s) yields
- consultations with agricultural experts in the area
- consultations with agricultural producers in the area
- estimation by a commission of "knowledgeable or informed persons"

or a combination of these.

164. When it is envisaged to utilize self-enumeration for the collection of crop statistics, a pilot survey should be conducted to test, investigate or study some of the following factors:

- the adequacy of the questionnaire and the capacity of the respondent to understand the concepts, to follow the instructions and to provide the appropriate answers
- the existence and type of written records (e.g. book-keeping records) on the agricultural activities of the holding
- the rate of non-response and the relevant characteristics of non-respondents compared to those of the total population under study
- the degree of inaccuracy due to memory lapses.

165. For interview surveys, different pilot studies and surveys are recommended. They cover:

- testing different types of questionnaires (and maybe on more than one occasion) to identify the most adequate one for collecting the required data
- investigation of the local units used for areas and weights, their variability from place to place (even when they bear the same name) and the preparation, for each region or sub-division, of a set of conversion factors to standardize the declared data
- testing the level of training of the enumerator, his capacity of understanding the concepts involved and of following the instructions, his ability in extracting from the respondent the required information and of recording it properly in the schedule
- testing the respondent's knowledge of the concepts involved and his capacity to provide the correct information in standardized or local units; his willingness to give accurate data on all or only on part of the required information (e.g. cost of seeds and other inputs, but not on output or sales) and testing his memory for past activities when the questionnaire includes some retrospective information on some items.

166. The use of sampling surveys to collect the data on crop areas and yields requires that a number of pilot studies and surveys be carried out in order to eliminate possible biases and to select the most appropriate or optimum sampling scheme within the available resources. Possible pilot studies and surveys cover:

- up-dating the frame and testing it for accuracy and completeness. The operation for testing the frame is usefully accompanied by a pilot survey to collect ancillary information on the primary units, an operation which would serve to improve the efficiency of sampling through proper stratification.
- The variability of crop areas and yields within and between the sampling units at each of the stages of sampling.
- The average time needed for:
  a) the listing of the secondary units in a primary sampling unit and the tertiary units in a second stage sampling unit, etc.

b) the travel from one primary unit to another, from one second stage unit to another, etc.

c) the completion of the questionnaire or schedule

d) the measurement of the area of a field

e) the delineation of a crop-cutting plot and for crop-cutting, processing and weighing the produce.

- On the basis of the above, the determination of the number of sampling stages, the size of the first, second and higher stage sampling units, the method of selection of the sample: simple random, cluster, systematic, etc.

167. When objective measurements of crop areas and yields are involved in the system of crop statistics to be established, the main type of pilot studies and surveys of interest are those dealing with the methodology and those dealing with the type of measuring equipment to be utilized. They are to test:

- the feasibility and accuracy of using the method of triangulation versus the method based on the lengths and directions of the sides of the perimeter of the field,
- the time needed, the accuracy and the total cost of using protractor and ruler versus the topographical "planchette" for sketching the field,
- the time needed, the accuracy and the total cost of using grids or planimeters or simple trigonometric formulae for calculating the area of the field,
- the time needed, the accuracy and the total cost of using programmable pocket calculators for obtaining directly the area of the field,
- the time needed, the cost and the accuracy of using the different measuring instruments: string, chain, tape, range finder, trumeter wheel, etc. for measuring distances.
- the time needed, the cost and the accuracy of using the different types of optical instruments for measuring angles or directions,
- the time needed, the cost and the accuracy of using the different instruments: string or wire, rigid frame, special tape, poles etc. to delimit the crop-cutting plot; a pair of scissors or other cutting implement to crop-cut the produce and balances to weigh it.

168. Before establishing the system for the continuous collection of crop areas, yields and production statistics, a pilot survey should be carried out to investigate the feasibility of the system under the specific agro-socio-economic conditions of the country. Subsequently, to permit a rational organization of the system and the selection of the most appropriate methods to implement it, an integrated programme of pilot surveys and studies, selected from the above, is to be formulated and carried out.

Tabulation and Processing

Tabulation

169. The tabulation programme should be prepared immediately after the formulation of the objectives of the statistical survey and should serve as the main basis on which the content and format of the questionnaires and schedules are constructed. It also influences the method to be used for the collection of the data. Thus, if more precise data on crop areas and

yields are required and especially when such data are to be cross-tabulated with the agricultural techniques and/or with the different inputs, the questionnaire would be more complex and the method for data collection cannot be based simply on observation or eye estimation. On the other hand, if the data are to be shown by small sub-divisions of the country, the questionnaire would be simpler and the method of collection should be based on some kind of complete enumeration (or a large-scale sample) using crop reporting or the interview method.

170. For crop statistics, the tabulation of the data could be very simple: for each crop or for the main crops only, the data on crop areas, yields and production are shown for the nation as a whole and for large sub-divisions of the country (e.g. states, provinces, agro-ecological zones, etc.). Or the tables could be more and more complicated showing the data for the different sectors of agriculture; by smaller sub-divisions of the country; showing the different types of areas and the different types of yields or production; according to certain particular agricultural practices, and/or according to different inputs, etc.

171. The list of general topics given in the section "Components of a Programme for Crop Statistics" para 79, covers not only the usual collection of statistics on crop areas, yields and production but also various studies on the effect of agricultural techniques, inputs, etc. on the yield and production, and special surveys like cost of production, utilization and disposal of the produce, etc. If information on such topics was tabulated and cross-tabulated in different ways and with other important variables (e.g. sub-divisions of the country, size of holding, etc.) the number of tables would be almost unlimited, a situation which is neither practical nor desirable. In what follows, a number of basic tables are listed as a guidance and illustration of what type of tabulations and cross-tabulations (not all of them necessarily essential) can be planned.

172. The following tables are of great interest to almost all countries and thus could be recommended for universal use as basic:

1. Extent of area, yield and production of annual crop (by crop) by appropriate sub-divisions of the country and sectors of agriculture and cross-tabulated with:
   - unimproved and improved seeds
   - irrigated and not irrigated
   - fertilized and not fertilized
   - treated with pesticides, etc. and not treated, and with selected combinations of the different inputs.

2. Extent, number of trees (productive and non-productive separately, yield and production of tree crops (by crop) by appropriate sub-divisions of the country and for the sectors of agriculture separately and cross-tabulated with:
   - irrigated and not irrigated
   - fertilized and not fertilized
   - treated with pesticides, etc. and not treated and with selected combinations of the different inputs.

172. Some useful and desirable cross-tabulations of crop areas are those in which the extent of the crop area is tabulated by appropriate sub-divisions of the country and

sectors of agriculture and cross-tabulated with

1. the type of area:
   - gross and net
   - pure stand (solo), mixed and associated crops
   - intended for ploughing, tilled, planted or sown, damaged, abandoned, fallow and harvested
2. the agricultural practices
   - number of ploughings and type of ploughing
   - method of sowing or planting
3. the inputs (separately or combined)
   - type of seeds and seeding rate
   - type and composition of fertilizers and manures
   - method of irrigation and amount of water.

174. Other useful and desirable tables are those in which the yield and production are tabulated by appropriate sub-divisions of the country and sectors of agriculture and cross-tabulated with

1. the type of yield or production: potential, expected, harvested, economic
2. the status of the crop: in pure stand, mixed, associated
3. the inputs (separately or combined)
   - type of seeds and seeding rate
   - type and composition of fertilizers
   - method of irrigation and amount of water
   - type and number of applications of treatments

175. When the collection of data is carried out through the enumeration of the holdings (complete or sample), another set of tables could be of interest. They are those in which the above data is cross-tabulated with the characteristics of the holding (e.g. total size, size of crop land, etc.) or the characteristics of the household associated with the holding (e.g. number of persons in the household who are economically active on the holding, etc.).

Manual processing [12]

176. In general, the number of variables in crop statistics and also the number of schedules is not very large and the collation and processing of the data can be easily done in the regional statistical offices since the operations reduce to transcription and simple summations or at the utmost the use of a fixed expansion factor (in the case where sampling techniques have been used). For this reason, the discussion here will be limited to manual processing.

177. The collation and processing of the data can be carried out in two different ways. The first consists of sending all individual schedules to the regional statistical office where the statistical operation of checking, collating and processing are executed. For the second, a hierarchical system: a decreasing order of statistical units (e.g. province,

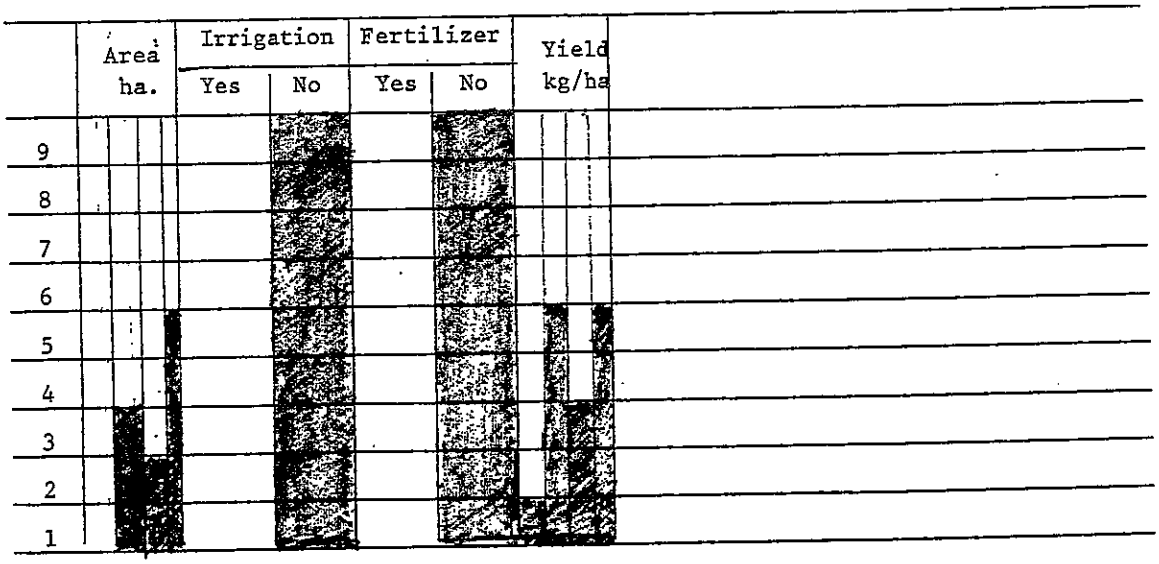
district, locality, area segment or holding) is organized. The data collected in the lowest statistical unit (e.g. holding) are checked and summarized (summed or expanded) for that unit and recorded on a summary card which is sent to the successive unit (e.g. locality), there all the summary cards from the lowest unit are checked and summarized, recorded and transmitted to the next higher unit. In such a case, the number of cards to collate and process at each level is very limited; moreover, different colours of summary cards may be used for different units (e.g. blue for holdings, red for localities, yellow for districts and green for provinces).

178. The simplest method for manual processing consists of the preparation of a file of tables in which each sheet consists of one of the proposed tables in the tabulation plan, with the corresponding column headings and horizontal characteristics. In each cell, tally marks are made or figures are transcribed from the schedules. If the number of tables to be constructed is large, it might be too laborious to go through the schedules afresh each time, and in such a case, it is advantageous to transfer the data to master sheets.

179. The precoded card system consists of assembling all data for a statistical unit or for a single crop on one card. The data are arranged in such a way that only the border (perimeter) of the sheet is used. As all the cards have the same lay-out, comparisons and summations of the data are greatly facilitated. There is the danger that transcribing the figures may introduce some errors in the results; however, this disadvantage is expected to be compensated by an easier and quicker use of the data. As in para. 178, these cards can be filled at different levels of sub-divisions of the country (region, province, district, locality) and can also have different colours for different levels.

180. The cardboard strip system is somewhat similar to the precoded card system. In this case, to each schedule or crop will correspond a strip which is sub-divided into a number of characteristics to be recorded. Each blank space is graduated (e.g. from 1 to 9) and divided into a number of columns corresponding either to a code or to units, tens, hundreds, etc. To record the data, the columns are blackened to the right level. The sketch hereafter illustrates the method of transcribing the information of data (Fig. 1)

Fig. 1. - Cardboard strip design



One advantage of this system is that it facilitates the regrouping of cards according to different characteristics or classifications. Since the information is visualized, the detection of errors becomes easier. In addition, these strips can be regrouped in such a way that the results of tables to be constructed are visualized, thus facilitating decisions on the tabulation programme.

CHAPTER III. MEASURING CROP AREAS

181. In the fifties and early sixties, a great handicap in the estimation of crop areas in developing countries was due to the illiteracy of the farmers and their ignorance of the standard units of measurement. To get over the difficulty, attempts were made by the statisticians to correlate crop areas with some other variable the magnitude of which was known to the farmers. Thus, it was thought that the amounts of seeds used, measured in local units, e.g. sacks, tins, could be declared by the farmers and used to estimate the cultivated area. However, the units were not uniform; they had to be standardized and a conversion factor had to be evaluated and used to translate the capacity or weight of local units into kilograms or pounds. In other cases, the cultivated area was correlated with the amount of animal or machine work needed to plough the land, e.g. the number of days of work of a pair of oxen to plough the parcel, the daily work capacity of a pair of oxen being used as the unit of measurement.

182. These attempts, although better than nothing, were in no way satisfactory and statisticians felt the need for objective methods, independent of the farmer's judgement, to estimate crop areas. Mainly as a result of efforts by FAO, some developing countries have established such a system. Because of the high cost of objective measurement such methods had to be limited to the most important crops. When more crops are covered at the expense of accuracy by reducing the sample size to minimize costs, the results may not be reliable except perhaps for area estimates at the national level or for large administrative units.

183. On the other hand, in developed countries where there is a long tradition of statistical inquiries and where the farmers are able to provide the required data on crop areas, the system generally used is a low-cost one based on crop reporting and/or interview of the farmers. However, there are reasons in some cases to suspect the reliability of answers given by farmers even in highly developed economies. Sample surveys with objective area measurement are therefore sometimes used in specific types of surveys in developed countries to estimate crop areas and also to control and check the data obtained through simpler and less costly techniques.

184. An integrated system in which low-cost surveys based on crop-reporting locality-wise, interview of the farmers, etc. are combined with sample surveys involving the measurement of crop areas, could be recommended at the present stage of statistical development of most countries. The share of each component in the programme of surveys will depend on the specific conditions of the country and the available resources (human, material and financial), as well as on the relative importance of the crops.

185. The choice of appropriate area measurement technique and the corresponding measuring instruments depends on a number of factors:

- existence of large-scale maps, aerial photographs, etc.
- type of cropping
- size and shape of parcels and fields
- configuration and profile of the land
- required degree of accuracy
- available resources (human and material).

186. The purpose of this chapter is to review and assess:

- the different methods of measuring areas (use of mapping material, actual measurement of fields and parcels, remote sensing)
- the corresponding field and office operations to be carried out
- the topographic and other measuring material.

Methods Based on Mapping Material

187. Where large-scale accurate maps are available, particularly if they show the actual positions of parcels and fields, and where it is not desired to have the area statistics associated with individual farms, a range of possible techniques for estimating crop areas is available. In a large number of countries such maps are compiled and kept up-to-date by the cadastral services for purposes of revenues. Cadastral maps show the boundaries and area of each parcel of land together with an identification number. The name of the owner and other characteristics of the parcel are also kept in a separate register.

188. In many developing countries such cadastral maps do not exist or do not cover the whole country. However, many countries have had, at one time or another, aerial photographs taken and survey maps prepared. The coverage of these maps and photographs is not always complete and the scale may vary from region to region; moreover, they are not necessarily up-to-date. For purposes of crop area measurements and when no field measurement on the ground is envisaged, the scale of the maps and photographs should be large enough, e.g. of the order of 1:10,000 (i.e. one square centimetre per hectare) or even larger if the crop fields are of small dimensions. It is to be noted that maps of a scale of 1:25,000 can be expanded photographically to twice their size without loss of clarity and thus can eventually be used.

Area sampling

189. The prerequisite for area sampling is the existence of a complete set of large-scale, accurate and detailed maps and/or aerial photos covering, without omission or duplication (overlapping), the entire territory or the domain of study. The first operation, to be carried out in this case, is the subdivision of each of these maps or photos (or each of a selected first stage sample) into "segments". The segments should be "natural geographic areas" delimited by natural borders, e.g. ridges, rivers, roads, etc. (fig. 2 shows a segment bounded by: a railroad, a river and a powerline). When these segments are numbered and maybe characterized through the recording of ancillary information, the maps or photos are transformed into frames of area sampling units (fig. 3) from which samples of segments to be investigated are selected.

190. In the case of cadastral maps, the fields are generally numbered and those falling within the sample segment can be identified and listed. The list of field numbers is then sent to the outposted staff in the areas concerned with instructions to enter against each of them the name of the crop occupying the field. It will be noted that, in the conditions assumed for this technique, the boundaries of the listed fields are quite clear and that they will be well known and clearly designated in local records. When more than one crop occupies a field, estimation of the area of each crop will have to be made subjectively or by measurement.

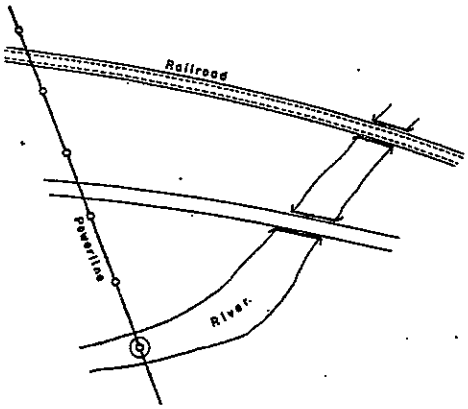


Figure 2. Illustration of the concept of a segment.

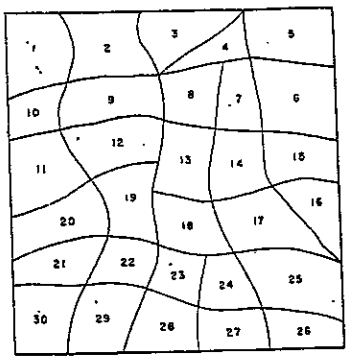


Figure 3. Frame of area segments.

19 1. When the boundary of the segment crosses a field (the powerline in fig. 4) the "closed segment" approach, in which the recording is confined within the actual boundaries of the segment and which implies that only that part of the field area which is within the boundaries is to be included, is not feasible unless the map or photo showing the boundaries of the segment is also sent to the enumerator. In this case, the enumerator has either to estimate subjectively the proportion of the area to be included or actually measure that part of the field. The first solution presents the defects of subjective estimation and the second that of over-burdening the originally simple survey.

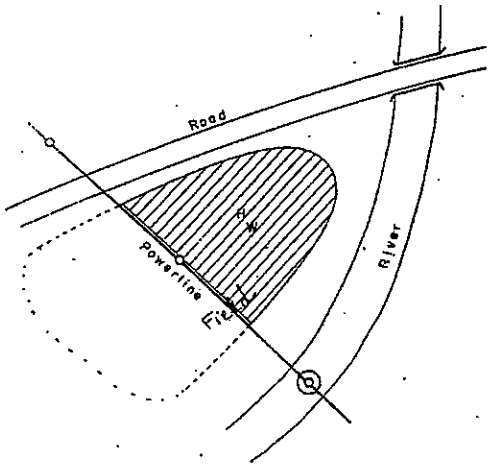


Figure 4. Borderlines of a segment.

192. An alternative solution is to use the "open segment" approach, i.e. to formulate some rule for associating the field to the area segment, a rule on the basis of which the whole area of the field is either included or excluded from the segment. To be valid, the rule should lead to unbiased estimates of crop areas. An example of such a rule could be the following:

> "A point on every field which can be defined rigorously, and which can be identified by the enumerators on the ground (e.g. the south-west corner), is employed as reference point. If this point for a particular field falls within the boundaries of the area segment, the field is regarded as being "in" the segment. But if the reference point is outside the segment, the entire field is considered outside the segment, even though some or the major part of its area may fall inside the segment."

193. When the parcels and fields are not numbered and registered in local and national records but are nevertheless clearly indicated on the maps, a variant of the above method (cf. para. 189) can be used. A section of the map containing the relevant segment(s) is sent to the local field officer who enters on the map the portions of the several parcels or fields which are occupied by designated crops and returns it to Head Office. At times, it might be necessary that the field staff will have to sketch accurately, within the segment(s), the portions of the land surface occupied by the various crops. The areas under the different crops are then estimated or measured (e.g. by planimeter) and converted to ground surface area.

Grid and point sampling

194. An analogous technique for crop area measurement, also based on the existence of large-scale, accurate and detailed maps or photographs, makes use of the grid sampling method. In such a case, even small administrative or agro-economic regions are covered by a large number of non-overlapping photographs or maps, which could be used as primary sampling units. In fact, if the scale is 1/10,000 the useful part of a normal aerial photograph covers only a land area of about 10 square kilometers. The method consists of the following: on each sample map or photograph (when maps or photos are considered as primary sampling units) a grid is super-imposed in which each square has a fixed known area (e.g. 10 ha). Each of the squares is given a serial number and one (or more) is selected as the ultimate sampling unit.

195. The procedure of identifying on the ground the crops in the different fields within the selected sample square follows the same lines as those given above (cf. paras. 189-192). The main difference between the two methods is that, in grid sampling the total area of the ultimate sampling unit is constant, while in the unrestricted area sampling the total area of the unit may vary widely. Thus, one advantage of grid sampling over unrestricted area sampling is that the variability of the data is smaller since the component of the variance due to the size of the unit is nil and also, the raising of the results from sample to the universe is much simpler. However, it might be much more difficult to identify on the ground the boundaries of the square than those of the segment which is a natural geographic area.

196. A variant of this technique is based on the use of point sampling, i.e. where the sample locations for crop observation take the form of a set of points within the primary sampling unit: the area covered by a map or a photograph. The selection of the sample of points can be random or systematic (e.g. the points of intersection of the lines in a grid).

The enumerator is provided with an enlarged photograph on which the sample points are drawn as the intersection of two branches of a cross. He goes to the precise place and takes note of the type of soil, the land use category and the crop.

197. The point sampling technique for the estimation of crop areas appears to be simpler than the actual measurement of the areas of the fields. Also, an enumerator can visit from 50 to 100 points on the ground identified on an aerial photograph in his day's work as compared with the small number of fields he can visit and measure using other techniques. A number of countries tried to estimate crop areas using this method. However, the results were not satisfactory. The main problems encountered were related to:

- the identification of the exact location of the sample point on the ground
- the identification of the type of cultivation
- the inaccuracy of the results when the area under the crop is a small fraction of the total area covered by the photo.

198. Figure 4A gives an illustration of systematic point sampling. The relevant information is:

- Area covered by photo = 2.4 km x 3.2 km
- Number of sample points = 48
- One sample point represents 16 ha land area
- Total driving (or cycling) and walking distance to identify the crops, etc. = 18.8 km

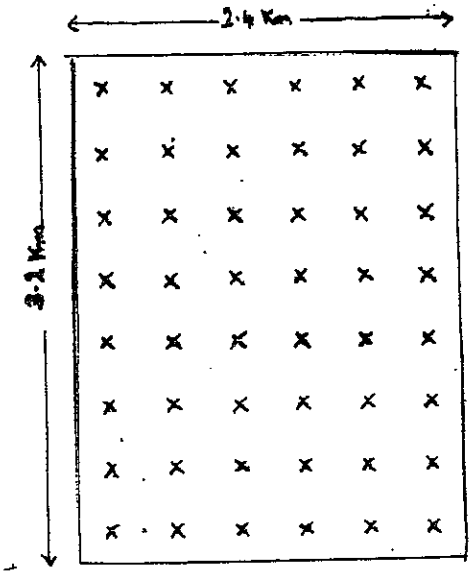


Figure 4A. Point sampling

199. Granted that the photographs show all the physical features, the pattern of parcels and fields changes in time and the sample point, which generally falls in between different physical features, cannot be easily and precisely located on the ground. Moreover, it might happen that the enumerators, consciously or unconsciously slightly shift the position of the sample point in such a way as to make it fall within a crop field when, in fact, it should belong to some other land use category (e.g. an empty unproductive lot). Errors due to these difficulties can be random and increase the variance of the results or they could be biases of unknown magnitude.

200. If the point falls clearly within a field in which a single crop is standing, the identification of the crop is quite easy. This is not the case when:

- the field has not yet been planted
- the field has already been harvested and there is nothing left to clearly identify the crop
- the point falls on a field of mixed or associated crop/s
- the point falls in-between fields bearing different crops.

Some of the difficulties can be overcome by a proper choice of the period of survey operations, others can be minimized by giving precise instructions to the enumerators. However, not all the errors due to the wrong identification of the crop can always be eliminated.

Table 4. Coefficient of Variation (%) Obtained from Point Sampling for Crop Areas in France

Land category \ Level	National	Region (lowest c.v.)	Department (lowest c.v.)
Arable land	0.48	1.37	3.05
Permanent meadows and pastures	0.56	1.83	3.15
Woods and forest	0.52	1.49	2.48
Agricultural not cultivated	1.21	3.04	5.27
Non-agricultural	0.87	2.43	4.47
Cereals	0.65	1.65	3.35
Weeded crops	1.85	4.00	6.36
Grapes and vines	1.80	3.03	5.00
Oilseed crops	3.59	6.42	10.4
Industrial crop	12.3	n.a.	n.a.
Fibre crops	8.41	n.a.	n.a.
Leguminous plants	7.39	n.a.	n.a.
Fodder crops	0.87	2.12	4.08
Fallow	3.77	9.13	15.6
Fruit trees	4.34	10.3	15.3
Soft wheat	1.00	2.50	4.60
Barley	1.20	3.17	6.50
Potatoes	3.80	9.53	16.3
Beetroots	2.68	4.45	6.78
Apples	5.35	15.8	20.9

201. A much more serious problem concerns the dimension of the sample size even when the scope and crop coverage of the survey are limited and the required level of precision comparatively low. In France, where a large-scale land use survey, based on point sampling (cf. Annex $2\text{-}B_1$), is carried out yearly, the confidence interval of the area data is narrow enough at the national level for land use categories and large groupings of crops. At the "Region" level, the confidence interval is on the average four times larger and at the "Department" level, it is on the average 10 times larger. Table 4 shows the coefficient of variation of the estimated areas (1) at the national level; (2) for the Region having the largest area of the land or crop category, i.e. which would have the lowest coefficient of variation; and (3) for the Department having the largest area of the land or crop category.

202. When point sampling for land use categories or crop areas is practised, it is essential, before the publication of the results, to ensure that the data are of an acceptable order of precision. No general rule can be given on the size of the sample since the degree of precision will depend on the sampling scheme. However, when the sampling scheme is a two-stage one with photographs as primary sampling units and points as the ultimate unit, a rough estimate of the order of magnitude of the expected coefficient of variation can be calculated. Table 5 shows the order of magnitude of the coefficient of variation when the estimate of the area is based on the indicated number (N) of points falling within a certain land or crop category.

Table 5. Order of Magnitude of Coefficient of Variation

N = Number of points falling in land category or crop fields	Expected coefficient of variation (per cent)
100	23
200	16
500	10
1 000	7.3
2 000	5.1
5 000	3.3
10 000	2.3

From Table 5 it is easily seen that if 100 points fall within a certain land or crop category, the length of the confidence interval (from .54 A to 1.46 A) of the area estimate A at the .95 probability level is 0.92 A, almost equal to the estimated area itself.

Remote sensing

203. Remote sensing is defined (20) in a broad sense as the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study; e.g. the utilization at a distance (as from aircraft, spacecraft or ship) of any device and its

attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy. The technique employs such devices as the camera, lasers and radio frequency receivers, radar systems, sonar, seismographs, gravimetres, magnetometres and scintillation counters. The technique discussed hereafter is limited to the one based on the use of satellites (space platforms distant a few hundred kilometres), scanners (instruments sensitive to electro-magnetic energy reflected or radiated from man-made and natural features) and computers.

204. Manned and unmanned satellites have produced imagery that is or could be useful. Manned satellites, such as Skylab, have operated only for relatively brief and irregular intervals, and the images obtained have provided only partial coverage. Unmanned satellites, such as Landsat I, II and III (launched in 1972, 1975 and 1978, respectively) have passed over the entire inhabited earth many times on a regular basis, providing almost complete coverage of the earth's surface.

205. Unlike manned satellites, unmanned satellites cannot effectively use ordinary photographic cameras and film; for example, there is no way to reload the cameras after the film is exhausted. Such satellites must use other sensing systems. The most common type of sensor used in these satellites is called a scanner. The scanner senses the amount of energy being reflected or radiated from a series of points, translates these sensations into numerical values, and radios these values to receiving stations on the earth. These values may then be processed to make pictures for use in the usual form of interpretation, or they may be refined and reformatted (put into another form and stored on magnetic tape) for subsequent use in a semi-automatic or automatic interpretation process involving a computer. The imagery is less detailed than the photos obtained from manned satellites; however, it contains much useful information.

206. Landsat II and III, orbiting the earth at about 900 kilometres, are capable of making such energy measurements for a square area of 180 km x 180 km any place on the globe every 18 days (or every 9 days if both satellite results are combined). Each of these square areas is broken into 7.7 million points (pixels) by the action of a line scanner. Each resulting pixel has four values associated with it representing four levels of energy being returned from the portion of earth surface the pixel represents, in each of the green (.5 - .6μm), red (.6 - .7μm), and two infrared (.7 - .8 and .8 - 1.1μm) portions of the spectrum. The spatial resolution of Landsat data is 79 x 56 m and each data point represents thus about half a hectare.

207. Remote sensing imagery used for the identification of earth surface features is dependent upon measurable variations in electromagnetic field strength. Variations are of three main types:

1. Spectral: These depend on the physical conditions of the surface cover type being sensed. As the electromagnetic energy from the sun strikes the cover type it will either be reflected back into space, absorbed and then emitted at a different wavelength, transmitted through the material (and lost for measurement purposes) or scattered depending on the geometry and physiology or physical make-up of the cover type. In as much as different combinations of these things happen or in as much as they happen at different wavelengths, spectral variations will occur.

2. Spatial: These arise because the spatial location of cover type A is different from cover type B. Measurement of spatial variations is dependent on a device that can measure the electromagnetic energy being returned at many spatial locations, such as a line scanner.

3. Temporal: Many cover types, and especially crops, change spectrally over time as they progress through growth and development stages.

208. The utility of using Landsat data to identify areas under specific crops can be assessed as follows:

> "any crop can be mapped using multispectral scanner data if, and only if, the spectral values associated with the crop are detectably different from the values of the other features to be mapped."

In order to identify the crops, it is also assumed that the spectral values corresponding to each cover type are known. For this, points representative of the different cover types must be located on the ground and some information about these locations collected. This is referred to as "ground truth" or reference data and, in general, the more of this ancillary information is available, the more reliable is the identification of the remote sensing data.

209. Some of the sources of inaccuracy of the data and/or inability to identify the crop are the following:

- the feature to be mapped is smaller than the spatial resolution of the scanner (e.g. very small fields in the traditional sector of mainly subsistence agriculture);
- the physical make-up of one of the features is very similar to that of other features, such that the spectral variation is not significant (e.g. tea was confused with other types of vegetation)
- appropriate wavelength bands for discrimination are not available (e.g. snow and clouds are not distinguishable with Landsat data);
- uncertainty about the location of the features due to inadequate ground truth data and/or improper use of it;
- spectral variations between cover types may exist at one time of the year but not at another.

210. The technical possibilities offered by remote sensing can be assessed on the basis of the amount of details in the classification of land use and land cover which can be identified. The U.S. Geological Survey (USGS) classification considers two levels: level I encompasses 9 categories of land use and land cover and level II encompasses 37 categories of which 10 are related to agricultural land, pastures and forests. The present Landsat II and III data provide information on an intermediate level between levels I and II. It is expected that Landsat IV, to be launched in 1981, will provide information on level II. The list of categories at the two levels is given below:

Land use and land cover classification system for use with remote sensor data (USGS 1976)

Level I	Level II
1. Urban zones and built-up areas	11 Residential zones
	12 Shops and services
	13 Industries
	14 Transport, communications and public services
	15 Industrial and commercial compounds
	16 Areas partially urbanized or built-up
	17 Other areas urbanized or built-up
2. Agricultural lands	21 Annual crops and cultivated meadows
	22 Fruit trees, vines, nurseries and horticultural cultivation
	23 Industrial livestock in fenced land
	24 Other agricultural lands
3. Savannahs and pastures	31 Grass savannahs
	32 Spiny savannahs, bushes, scrubs
	33 Mixed savannahs
4. Woods and forests	41 Forests of caducous trees
	42 Evergreen forests
	43 Mixed forests
5. Waters	51 Rivers and waterways
	52 Lakes
	53 Reservoirs
	54 Bays and estuaries
6. Humid zones	61 Wooded marshes
	62 Non-wooded marshes
7. Dry zones	71 Salted dried lakes
	72 Beaches
	73 Sandy zones other than beaches
	74 Barren rocks
	75 Uncovered mines, quarries, gravel pits
	76 Transition zones
	77 Mixed dry zones
8. Tundras	81 Bushy and spiny tundras
	82 Herbaceous tundras
	83 Dry tundras
	84 Humid tundras
	85 Mixed tundras
9. Snows and ice fields	91 Everlasting snow fields
	92 Ice fields

211. From the above, it can be seen that, at present, there are limitations to the use of satellite data for the estimation of areas of land use categories and more so for the estimation of crop areas. However, satellite imagery and data may be useful for agricultural statistics in a variety of ways and will be more so in the near future. In fact, more progress in resolution power and other improvement in satellite imagery must have been achieved but not yet made public in view of its strategic significance and, hence, classified information and secrecy are still quite restrictive. Such restrictions tend to be relaxed and the prospects for better and more extensive use of satellite imagery are quite good.

212. The classification of areas into strata is a common procedure for sampling purposes. If detailed maps or aerial photographs already exist or if data by small areas from a census of agriculture are available, satellite imagery currently available would probably be used as a supplemental rather than the primary source of information for delineating strata. If mapping information or available data are very poor or non-existent, then satellite imagery could be the primary source of information for delineating strata and for delineating sample areas.

213. One way to use satellite imagery in stratification is to determine the proportion or density of an element in an area and prepare a map. The element could be the percentage of total land area that is cultivated, percentage in pasture, amount of barren land, etc. The analyst will then need to superimpose appropriate area boundaries on the imagery and determine a set of classes from the data that are developed.

214. During the last decade, many studies were carried out to assess the possibility of satellite data utilization in agriculture for the estimation of land use and crop areas, the forecast of crop production, etc. The results varied widely and they were not always satisfactory even when the number of classification categories was very small.

215. Two main methods are used for the evaluation of the accuracy of the estimate $\hat{A}$ of the area under a land cover category L:

1. comparison of the estimate obtained through remote sensing imagery with the area estimated or obtained through the traditional methodology;

2. comparison of the pixels which are identified as belonging to the land cover category L_i with the corresponding ground truth and calculating the ratio of the number of pixels properly identified to the total number of pixels identified as belonging to category L_i.

216. The first method is obviously not very efficient and can only be useful in assessing the development of remote sensing accuracy. Even when the two estimates are equal, the area estimated through remote sensing imagery may be subject to two types of errors:

1. it might include areas which do not belong to the specific land cover category;

2. it might exclude areas which do belong to the specific land cover category.

The two types of error might or might not cancel each other. In fact, it is the existence of these two types of errors which makes difficult the evaluation of the efficiency of the classification of areas using remote sensing imagery.

217. To utilize the large volume of satellite imagery data efficiently and to provide the type of information desired, computer aided analysis of the data is commonly performed. One widely accepted analytic concept known as LARSYS takes a maximum likelihood pattern recognition approach to classifying data such as that described above. This approach involves locating points representative of the cover types of interest, and using the spectral properties of those points to decide to which of those cover types an unknown point is most likely to belong. Other classification concepts include clustering, level slicing, minimum distance, and sample (or field) classification.

218. Other significant applications of remote sensing in agriculture are the following: The spread of desert and deterioration through erosion can be observed over time. Effects on the size of the cultivated area and, to a lesser degree, on the quality of crop production can be measured. Also, major changes can be observed in land use, such as between forest and crop land, and in the pattern of occupancy, such as a shift from large fields to small individual holdings. So far, ability to distinguish individual crops and the same crop at different growth stages appears to be limited, especially in small fields or when several crops are grown in the same field. Future or existing classified technical developments may result in images with higher resolution and which can be reproduced at larger scales. This is expected to make satellite images much more useful for many programmes of agricultural statistics, and their applications deserve to be kept as a continuing concern.

219. Remote sensing technology, as a new tool to collect agricultural statistics, especially in developing countries, would advantageously replace in the future the cumbersome and costly techniques of on the ground area sampling, objective measurement of crop areas and yields, etc. At the present stage of development the new technique requires the undertaking of a large ground truth operation and improvement in the level of accuracy of the data. Although remote sensing techniques will not, in the near future, substitute completely for some of the traditional agricultural statistical methods, it can supplement or serve as a basis to improve the quality of many types of agricultural statistics. Hence maximum use of remote sensing techniques can be made in conjunction with existing techniques subject to the availability of more information and to further improvements in the techniques used.

Land Surveying Methods

220. The purpose of land surveying is to determine the form and extent of a portion of the earth's surface by linear and angular measurements so as to construct a map, plan or a detailed description of it. Surveying methods vary widely and depend on the availability of resources and instruments and on the required level of accuracy of the results. In general, the methods and instruments used in the Survey Departments of the countries are too sophisticated, costly and time consuming for use in measuring crop areas. In what follows a review is given of simple methods and inexpensive instruments used in the agricultural statistics units of the ministries of agriculture in some countries, but which, nevertheless, provide sufficiently accurate results in measuring crop areas. Besides the methods of measuring parcels and fields, an assessment of the instruments and a review of the methods of evaluating estimates of crop areas will be covered.

Measuring parcels and fields

22 L. Land parcels and crop fields, in many developing countries, have irregular boundary lines which are not necessarily straight lines. For this reason, a method which has frequently been used in the past to measure crop areas was that of rectangulation. For rectangulation, a simple way to obtain the area was to measure the length of the parcel or field somewhere more or less across the middle and then determine through eye estimation the position of the average width and measure it (fig. 5a). The method was slightly improved by having three measures of the width: two near the two ends of the field and one in the middle (fig. 5B). Later it was thought to improve the estimation of the area further by measuring the width at a large number of equidistant positions thus dividing the total area into a number of rectangles or more precisely a number of trapezia (fig. 5c).

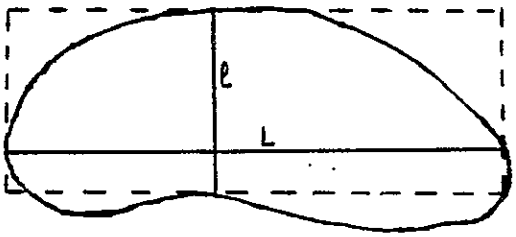


Fig. 5a. A = Lxl = 22.3

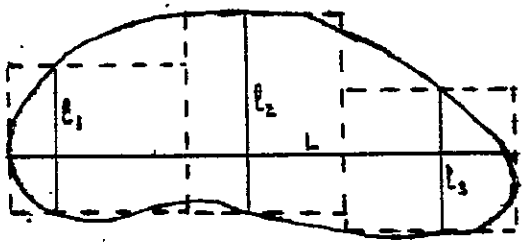


Fig. 5b. $A = L \times \bar{l} = 19.5$

$$\bar{l} = \frac{1}{3}(l_1+l_2+l_3)$$

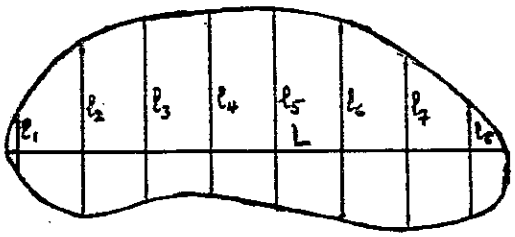


Fig. 5c. $A = L \times \bar{l} = 20.6$

$$\bar{l} = \frac{1}{8}(l_1+l_2+\ldots+l_8)$$

22.2. When the shape of the field is not too complicated, the method of rectangulation can be useful and its reliability for estimating crop areas is acceptable. For example, the estimates of the area of the field shown in figures 5a, 5b and 5c differ from the true value of the area (20.2) by about 10%, 3% and 2% respectively. However, on paper or map, it is easy to determine the positions at which the different widths should be measured but this is not the case when the operation is to be carried out on the ground and the errors could

be much larger. Moreover, in order to measure the length and the different widths, the enumerator may have to enter in the field and may trample the crop which would be disagreeable to the farmer.

223. To get over the difficulty of curvilinear boundaries of fields, the first operation is to transform the field into a rectilinear closed figure and to demarcate on the ground the vertices of the equivalent polygon by poles or pegs. This operation is to be carried out in such a way as to compensate for the areas left out of the field by an equivalent area added in from the land surrounding the field.

224. As an illustration, the contour of the African continent is taken to represent the curvilinear boundaries of a parcel of land or a field (many crop fields in developing countries have more complicated shapes). Figures 6a, 6b and 6c show different attempts to produce equivalent polygons, namely, a quadrilateral, a hexagon and a dodecagon respectively. The percentage error in the estimated area due to this operation is not very high: 4% in the case of the quadrilateral and less than 1% in the case of the dodecagon.

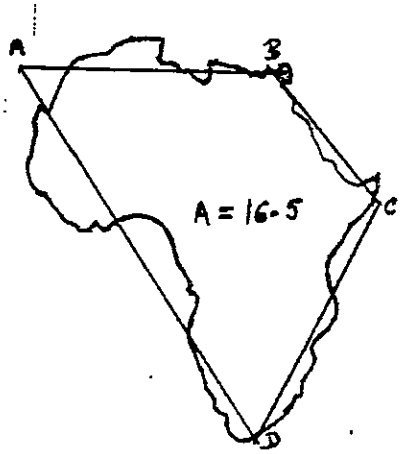


Fig. 6a. Quadrilateral

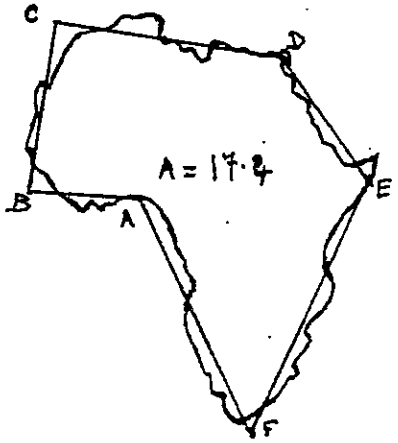


Fig. 6b. Hexagon

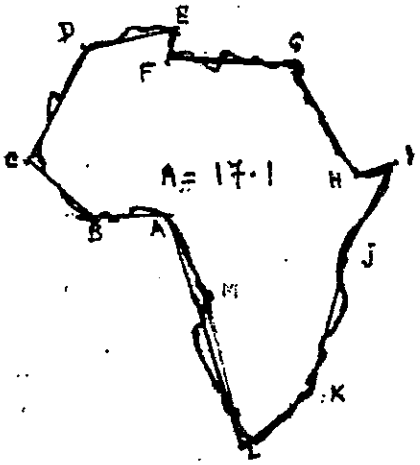


Fig. 6c. Dodecagon

225. It is to be noted that, theoretically, the more sides the polygon has, the better is the accuracy of the resulting estimated area. However, with more sides and eventually angles to be measured, the enumerator is liable to make more and larger measuring errors. For this reason, it is recommended that the number of sides of the equivalent polygon be kept reasonably low: from four to ten sides in most of the cases and to exceed ten sides only in exceptionally complex field shapes. From the above illustration, it can be seen that the difference in area between the hexagon (6 sides) and the dodecagon 12 sides) is negligible: about 0.6%.

226. The operation of compensation of areas (areas excluded = areas included) can be done globally in an easy way when the boundary of the field is totally visible (e.g., when the crop is low and there are no intervening obstacles). In the opposite case, when the boundary is not totally visible but only visible by parts at different positions of the viewer, the compensation has to be carried out separately for each visible part, i.e., each straight line must include and exclude equal areas.

227. It is now assumed that the boundaries of crop fields are rectilinear and the field is a plane polygon with well identified vertices. A plane polygon can be subdivided into a number of triangles with a common vertex (condition not indispensable but useful). The common vertex of the triangles can be one of the vertices of the polygon, a point inside the field or even a point outside the field. The area of the field can be evaluated as the algebraic sum of these triangles. This method of measuring areas is called triangulation. Figure 7 shows how the area of the hexagon of figure 6b can be divided into the four triangles: ABC. ACD, ADE and AEF.

228. Area measurement by triangulation can be feasible only when all the vertices of the polygon representing the field can be seen from one particular point. Moreover, it is essential that all the distances between the fixed point and the vertices can be easily measured. This last condition implies that either the farmer allows the enumerator to measure distances across the field (with the risk of trampling the crop) or that the distance measuring instrument does not require that the surveyor enters the field (cf. para. 255).

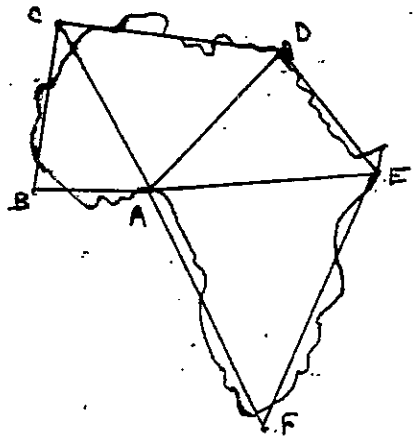


Fig. 7. Triangulation

229. The advantage of triangulation over other area measuring techniques is that it requires only that distances be measured since the triangle is uniquely determined when its three sides are known. On the other hand, triangulation does not permit the direct discovery of errors of measurement. In fact, any three distances will determine some kind of triangle except in the rare case where the error is so gross as to produce three distances which could not constitute a triangle, i.e. in the case where one of the sides is equal or larger than the sum of the two others. In order to minimize the risk of such errors, a fixed vertex should be selected in such a way as to avoid the formation of a very obtuse angled triangles.

230. Whenever it is not possible to find a point from which all the vertices of the polygon are visible or when it is not allowed to enter in the field, but it is possible to walk and

measure along the perimeter, the method of measuring the field area necessarily involves both measuring distances (the sides of the polygon) and measuring angles: either the angles included between two consecutive sides or the angles which each side makes with a fixed direction (e.g. the north).

231. A polygonal crop field of n sides is uniquely determined when (n-1) sides and (n-2) enclosed angles are known or when the length and bearing (horizontal angle with a fixed direction, e.g. the north) of (n-1) of its sides are known, the last side being obtained by joining the two end points. This is true if and only if the (n-1) sides and directions are free from error which is never the case in actual measurements. The practice of measuring only (n-1) sides and directions may produce inaccurate results and, moreover, the magnitude of the error, which might be very large, cannot be assessed. In order to estimate the possible errors and subsequently accept or reject the set of measurements, it is essential that all the n sides and the n bearings (or angles) be measured.

232. When the n sides and bearings are measured and the polygonal field plotted at an appropriate scale, it invariably happens that the figure does not close: the two end points (first and last), which should coincide, are some distance apart. This distance has been called the closing error (or error of closure). If the closing error is below a certain limit, the measurements can be accepted but the sides and angles have to be adjusted in such a way as to make the figure close properly. If the closing error is above the fixed limit, the measurements have to be repeated on the ground. Figure 8 shows such a closing error.

233. The upper limit of the acceptable closing error depends on the required accuracy of the data on areas and it can be expressed in terms of either the perimeter or the longest diagonal. The upper limit of the acceptable closing error could be taken as 2 percent of the perimeter which would produce a probable error of 4-5 percent in the estimated area. However, in countries where enumerators are not well experienced in measuring areas or when the measuring instruments are not very precise, the upper limit of the acceptable closing error can be raised to 5 percent of the perimeter.

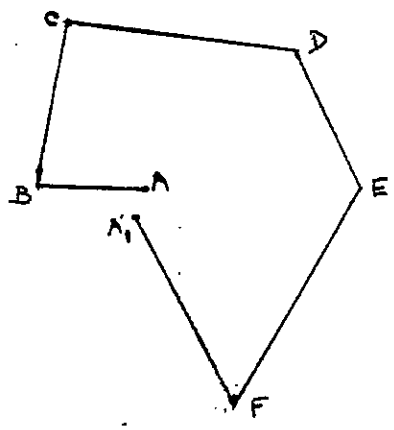


Fig. 8. Closing error AA_1 at the limit of acceptance

234. When the closing error is acceptable, there are different methods to adjust the sides and/or the angles in such a way as to make the polygon close. Some of the methods are reviewed in Annex 5 and the adequacy of their performance is empirically assessed.

235. The method recommended here is the following: -

Let $\vec{V}_1, \vec{V}_2, \ldots, \vec{V}_n$ be the n vectors representing the sides of the polygon and $\overrightarrow{AA}_1$ be the closing error vector.

From each vector $\vec{V}_i$ $(i = 1, 2, \ldots, n)$ subtract $\frac{1}{n} \cdot \overrightarrow{AA}_1$, the new set of vectors $\vec{V}'_i = \vec{V}_i - \frac{1}{n} \overrightarrow{AA}_1$ will close perfectly.

Practically, if the polygon is represented by ABC ... LA', the operation of adjusting the sides and angles consists in shifting the point B along the direction $\overrightarrow{A_1A}$ a distance equal to $\frac{1}{n}$ times the length of AA_1, shifting the point C a distance $\frac{2}{n} AA_1$ and so on. The last point A_1 will be shifted a distance $\frac{n}{n} AA_1$ and so coincide with A. Figure 9 shows such an adjustment.

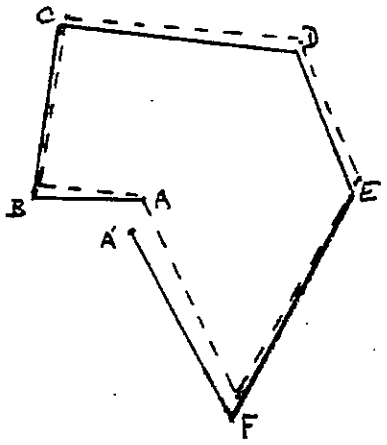


Fig. 9.

Closing the polygon

236. As mentioned before, agricultural statistics are concerned with the cadastral crop areas and areas measured on a horizontal plane. In hilly regions, from a fixed point, some of the sides of the field may be sloping upwards, others horizontal and some more sloping downwards. If the length of the sides are measured on the slopes, the polygon is no more on a horizontal plane and, in general, will not close even when the measurements are extremely accurate. For these reasons, the measurements to be carried-out for each side are:

- its length,
- its bearing and
- its slope (vertical angle with the horizontal).

The projections of the sides of the field on the horizontal plane (i.e. the lengths of the sides multiplied by the cosine of the corresponding slope angle), together with the bearings will constitute the elements for calculating the area.

237. Now, since the cosine of small angles is very nearly equal to 1. the error of using the length of the side on the slope instead of the horizontal projection can be negligible when the slope is very small. For slopes of 5°, 10°, 15° and 20°, the relative error introduced by using the length of the side on the slope are 0.4%, 1.5%. 3.4% and 6.0% respectively. On the basis of these data, whenever the angle of elevation or depression is less than or equal to ten degrees the slope should be ignored.

Assessment of the surveying instruments

238. In developing countries where measurements of crop areas are an essential continuous operation and where the enumerators, in general, are of the multipurpose type: at the same time, extension workers, interviewers, surveys, etc., the measuring operations and the instruments have to be as simple as possible. For this reason, the FAO has continuously been experimenting with different types of measuring instruments and, whenever new equipment appeared, it was tested for accuracy and practicability. Only those instruments

with an acceptable level of accuracy, easy to utilize and not too expensive, were recommended for use in developing countries. In what follows, those instruments most adapted to the measurement of crop areas are reviewed.

Measuring distances

239. In developing countries most of the farmers do not know the magnitude of the areas under their crops and the fields had to be measured by the available field staff in collecting agricultural statistics. The staff, not being specialized in land surveying techniques, had to be trained on simple methods, namely, rectangulation using the length and width of the field and measuring distances through pacing, i.e. walking at a normal gait and counting the number of steps to cover the distance. The steps are then converted to standard units.

240. At the beginning, an average length of steps (usually 0.83m) was used for all the enumerators. Then, in order to take into account individual differences, it was recommended to calibrate the step of each enumerator by pacing a well known distance and use it as a conversion factor. However, it was soon discovered that the length of the pace of the same enumerator changes according to the type of surface: sandy soil, clay, uneven ground, etc., and also according to the enumerator's state of health and fatigue and it was therefore necessary to calibrate the step several times a day which took away most of the advantages of the pacing method.

241. There is also a risk of miscounting the number of paces especially when this number is large. In order to eliminate this risk, a simple instrument the pedometer was proposed. It consists of a digital reader and a dial and the movements of the body for each step taken are registered and shown on the dial. The pedometers have to be tested to check the readings before they are used as some of them may be out of order.

242. For the above reasons, the pacing method for measuring the length of sides or diagonals of a field is not recommended and, in fact, has been discontinued in almost all countries. However, it could be used, even without calibration, when random points are to be selected within a field (c.f. para.303) for the purpose of laying crop-cutting plots.

243. Other very simple means of measuring distances which have been and still are used in developing countries are the standardized cord and the wooden pole. A cord of fifty meters has been used for the allotment of parcels 50m x 50m of communal land to the members of the village in many African countries. For the estimation of crop areas, the cord should be of a non-extensible material (which is not always the case) and care should be taken to avoid wetting it, otherwise its length would be altered. A wooden pole, the Kassaba, of 3.55m has always been used to measure the sides of fields in Egypt. In measuring large fields or parcels, there is the risk of miscounting the number of kassabas.

244. In the past, the classical method of measuring distances was the surveyor's chain. The chain is composed of metal straight links with circular ends connected by rings. Each end link is provided with a handle. Each link is 0.20 m long measured from the centre of one connecting ring to the centre of the next. The usual chain length is 20m (100 links) but there are 10m and 50m chains. Similar chains graduated in yards and feet are also available. Two men are required in measuring a distance AB with a chain: one man holds one end of the chain at the point A while the other stretches the chain on the ground along the direction AB and marks the point A_1, corresponding to the end of the chain. Then, the first man moves to the point A_1 and the operation is repeated as many times as necessary.

The distance AB is calculated as so many complete chains plus a number of links.

245. The advantage of the chain is that it is a cheap strong instrument. However, it has a number of disadvantages

- it is heavy and not easy to handle
- if not handled carefully, the links often tend to bend thus reducing its length and overestimating the distance
- over a long distance, there is a risk of forgetting to count a chain length
- when the ground is uneven (clumps, clods, etc.) the chain is not placed on the ground but held a few centimeters above which introduces a slight error due to the catenary effect.

246. The metallic or plasticized tape has displaced the surveyor's chain as a simple low-cost instrument for measuring distances. Tapes are wound on a special reel and are graduated in meters, decimeters and centimeters or in yards, feet and inches. They are available in different lengths - 20, 30 and 50 meters or 50 and 100 feet. They are used in the same way as chains but they have a number of advantages:

- not liable to bend and the catenary effect is almost inexistent
- easier to handle, and
- generally more accurate.

However, tapes break easily and if not handled carefully and cleaned after use, the metallic ones tend to rust and the plasticized tapes may lose the markings of the graduations.

247. Although the above measuring instruments (chains and tapes) are not very costly, however, the running expenses are high since two persons are needed to do the measurements. The remuneration of two persons, even if one of them need not be a professional enumerator but simply a labourer will, in the long run, be more expensive than the use of more costly instruments which can be managed by a single person. Such instruments are the Topofil, the Trumeter or Smith Wheel and the Optical Range Finder.

248. The topofil is a measuring device fitted with a non-recoverable light and strong string and a counter which registers distances in decimeters, meters and hectometers. The string runs out of the instrument as the enumerator walks the distance to be measured. In appearance it is like a small case and is carried by the enumerator. The procedure to use the topofil is simple: the enumerator fastens the end of the string to a fixed point and sets the counter at zero; as the enumerator walks the distance the string unrolls and the counter registers the length of the string unrolled; at the terminal point the enumerator reads on the counter the length of string unrolled which is then cut and discarded.

249. The topofil has the following advantages:

- any distance not longer than the length of the string on the reels can be measured in one single operation (maximum length 5480m)
- the speed of measurement matches the gait of the enumerator
- the enumerator can read the counter at any intermediate point and set back the counter to zero, and
- as the distance is recorded mechanically, there is no danger of miscalculating long distances.

250. The disadvantages of the topofil are the following:

- it is very costly as an apparatus but also its running cost is high since a reel can measure at most 20 fields of small dimensions (about 5 ha.)
- the topofil case is rather heavy to carry over long distances, and the string sags slightly and may even rest on the ground or on the plants.

251. A graduated wheel, a handle to push it and a counter on which are registered the number of revolutions of the wheel constitute the main elements of the Trumeter or Smith Wheel. The circumference of the wheel is either one meter or one yard. At the starting point, the enumerator sets the counter at zero and pushes the wheel along the line, the length of which is to be measured. The reading on the counter plus eventually the length corresponding to an incomplete revolution gives the length of the distance under consideration.

252. The trumeter wheel has many advantages:

- its cost is not very high and there are no running expenses
- it is easy to manage, the enumerators need not have any special training
- it is very accurate on smooth dry land, and
- the mechanical recording of the number of revolutions eliminates the risk of mistakes in counting.

253. However, it has also some slight drawbacks:

- conditions are not always suitable for using wheels: very rough ground, ploughed land, irrigated and humid land, etc.
- it cannot be used for direct measurement of horizontal distances when the land is sloping, and
- when the land surface is undulating the wheel measures the wavy curve and not the straight line.

254. During the last decade, a number of optical range finder instruments (tachymeter, range finder, etc.) for measuring distances have been evolved. They differ widely in range (from two to thirty meters up to fifty to one thousand five hundred meters). They also vary in degree of accuracy and price. For measuring crop areas, especially in developing countries where fields are generally small in size, the most adapted are those with a range of the order of 10 - 100 meters and an accuracy of 98 per cent at least for that range.

255. The instrument is mainly composed of a telescope, a rangematic or telemeter device, dials for focussing the images and for bringing them together and a graduated scale on which the distance can be read. To obtain optimum accuracy the object to be sighted should be conspicuous and with good contrast. For this reason the poles, to be placed at the vertices of the polygon representing the crop field, and which are to be sighted through the eye-piece of the instrument, should be painted in stripes of two contrasting colours (e.g. red and white).

256. The operation of these instruments is quite simple. The enumerator looks at the pole through the viewfinder. It will appear as a double image. He or she focusses the

the eye-piece until the images are very sharp. Then, he or she turns the range dial until the two images coincide producing a single sharp-edged image and reads the distance on the scale. In some of these instruments the two images do not coincide but are brought into line, or more precisely, the top of the lower image just touches the bottom of the upper image. It is useful, especially in the case of critical readings, to take two or more recordings and average them. Although the operation of these instruments is not complicated, enumerators will need a little practice on well known distances to train their eye to recognize when the images are in perfect coincidence before they can make accurate measurements.

257. The optical instruments for measuring distances have the following advantages:

- they require normally only one operator who does only need to walk the distance to place the sighting poles
- they are time saving as the reading of the distance is almost done on sight
- in the case of triangulation, the enumerator does not enter in the field and trample the crop.

Measuring angles

258. The simplest instruments to measure an angle BAC is the pantometer. It consists of a hollow cylinder divided into two by a plane perpendicular to its axis. The contour of the lower part is graduated from 0^{o} to 360^{o}. On the zero mark there is a sight or eye-piece which is held by the enumerator close to his eye and, on the opposite side, at the 180^{o} mark, there is an "object" window. The upper section of the cylinder can be revolved on its axis. To measure the angle BAC, the apparatus is placed on a tripod at the point A and the points B and C are indicated by coloured poles. The apparatus is so placed as to sight the point B through the sight vanes of the lower section of the cylinder which is then locked in that position making the plane of sight coincide with the direction AB. The upper section is then turned until the point C is seen and the plane of sight coincides with the direction AC. The angle BAC is then read from the graduations. The pantometer has rarely been used for measuring crop areas due to the fact that it is not easy to operate and that the sighting system through vanes is not very good for long distances.

259. The instrument generally used in agricultural statistics for measuring bearings is the compass. Many types of compasses, more or less expensive, have been used in the last decade. For the level of accuracy required in agricultural statistics, lately, the FAO has been recommending, after having tested it in many surveys, a relatively low-cost compass. It is compact, light and flat, it has no adjustable parts which makes its operation quite simple and it will stand up to heavy duty. Handled properly, the instrument will give readings with an accuracy of half a degree approaching the performance of very expensive compasses.

260. For its operation, the surveyor, with both eyes open and with or without eye-glasses, aims the compass so that the hairline is superimposed on the target when viewed through the lens and reads the bearing on the scale. The only difficulty is in the superimposition of the hairline on the target and enumerators may need to spend some time in practicing before they will be able to make accurate measurements.

261. Iron and steel objects close to the compass, like a wristwatch or steel-rimmed eye-glasses, may cause deviation. Whenever possible, such objects have to be removed to a safe distance. Also, large structures like buildings, reinforced concrete quays, etc., will cause deviation. A reverse sighting from the opposite end of the target line will show up if such a deviation exists or not.

262. When slopes of the sides of a field are steep, as generally the case in hilly areas, elevation difference of the end points of each sloping side has to be ascertained and the slope angle is to be measured in order to project the distance on the horizontal. Two small pocket instruments have been used to measure slopes: the clisimeter and the clinometer.

263. The clisimeter consists principally of a heavy suspended body or pendulum which rapidly assumes an exact vertical position when the instrument is held vertically. On the upper section of the instrument, there is a collimator on which is fixed the microphotography of a shape scale. In use, the enumerator holds the clisimeter by its suspension ring in such a way as to keep his eye very close to the clisimeter lens and see simultaneously the lines of the scale and the distant target which should be at the same height from the ground as the clisimeter lens. The reading of the slope is then direct since the line of sight is parallel to the slope of the ground.

264. On the other hand, the clinometer is a light compact box with a parallax-free lens, a scale card and a hairline. Unlike the clisimeter, the instrument is not held vertically but is aimed at the target by raising or lowering it until the hairline is sighted against the target point that is at the same height from the ground as the eye of the enumerator. The position of the hairline against the scale gives the reading. The scale being graduated in degrees, the accuracy of both the clisimeter and clinometer can easily be of the order of half a degree.

Evaluation of crop areas

265. For the evaluation of crop areas on the basis of the land measurements, two groups of methods have been used. In the first group the primary data is used to produce a sketch of the crop parcel or field at a given scale, the area of the sketch is measured or calculated and the figures are then reconverted to give the actual crop area. In the second group, the primary data are used directly to calculate the area. It is obvious that the risk of errors and their dimensions in the first group of methods are much larger than in the second since they include errors of sketching and errors of scale conversion and reconversion of the data. However, the second group methods are not always feasible and could be more expensive than those of the first group.

266. Before sketching the polygon representing the crop parcel, the lengths of the sides have to be reduced to a reasonable size. An optimum size of the sketch (which would minimize errors of sketching and measuring) is a size large enough to almost fill a normal sheet of paper (20 x 30cm). On this basis, the longest diagonal of the sketch should be less than 30 cm or in certain cases less than 20 cm. Since the largest diagonal is less than one-half of the perimeter, a simple formula to determine the order of magnitude of an optimum scale is

$$\text{scale} = \frac{1}{2P}$$

where P is the perimeter of the parcel measured in meters or yards and rounded to the hundreds.

267. An . illustration, consider the hexagon in Fig. 6b. The sides AB, BC, ..., FA are 172, 231, 363, 255, 442, 410 meters respectively. P is equal to 1873m, 2P = 3746m and the recommended rounded scale is 1/4,000. In such a case, the sides of the polygon in the sketch will be 4.3, 5.8, 9.1, 6.4, 11.0 and 4.3 cm respectively and the longest diagonal 17.3 cm which shows that the sketch will almost fill a normal sheet of paper.

268. Using such a formula, for each individual case, would mean that for almost each parcel, a new scale is to be used which, apart from complicating the work, will increase the risk of errors. It is better to reduce to as few as possible the number of different scales. The following three scales are recommended.

Perimeter in Mts. or Yds.	Reasonable scale	Expected area
less than 350	$\frac{1}{500}$	less than .8 ha. or 2 acres
350 - 750	$\frac{1}{1000}$	.8 - 3.5 ha. 2 - 9 acres
750 - 1500	$\frac{1}{2000}$	3.5 - 15 ha. 9 - 35 acres

269. Sketches are to be made only when the polygon is determined through the knowledge of the lengths and bearings of its sides (they are not needed in the case of triangulation), and the operation can be carried out either in the field or later in the office. The simplest low-cost instruments for sketching area are a plane table and/or a drawing board, a graduated ruler and a protractor preferably a complete circle.

270. A more sophisticated and costly instrument for sketching is the Topochaix portable drawing board. It consists of: a frame, a sliding plaquette, a rotating circular protractor, a graduated diameter to serve as a ruler, transparent tracing paper and paper rollers and, different devices for adjusting the protractor, raising and lowering the plaquette and turning the paper rollers. This instrument is not difficult to operate in the field and the enumerators need little training on its use.

271. Different methods have been used for the calculation of the sketch areas. They are based on different concepts or instruments:

- triangulation
- weighing
- grid and
- planimeter.

272. In the triangulation method, diagonals are drawn in the sketch to convert the polygon into a number of triangles, the sides of which are measured. The area of each triangle is then calculated by applying the formula

$$A = \sqrt{s(s-a)\ (s-b)\ (s-c)}$$

where a, b, c are the three sides of the triangle and s is the semi-perimeter $s = \frac{a + b + c}{2}$.

The area of the polygon is the algebraic sum of the areas of the triangles.

273. The weighing method presupposes that:

- sketches of the same crop are all drawn to the same scale
- the paper on which the sketches are made is homogeneous in texture and weight and is not affected by variations in atmospheric humidity, and
- an analytical balance sensitive to 1 mg is available.

For the calibration, a number of squares representing one hectare each are drawn on the paper, cut and weighed. The average weight will be used to evaluate the crop areas. The method is not very accurate especially when the crop fields are small in size as is the case in traditional agriculture in developing countries.

274. Two versions of the grid system exist. The first is based on squares of a certain dimension and the second on points representing a certain area. The grids are on transparent paper and as placed on the sketch. The perimeter of the polygon is sometimes traced on the grid for greater precision. The system is based on counting the number of squares or points within the perimeter.

275. When millimeter transparent paper is used as a grid, different types of squares can be used in counting: first, the number of squares of 1 cm side are counted, then in the incomplete 1 cm squares, complete squares of $\frac{1}{2}$ cm side are counted and divided by four; the remaining incomplete squares of $\frac{1}{2}$ cm side, whatever be their size, are counted and divided by eight. The sum of these three figures gives the area of the polygon in square centimeters.

276. In the same way, the grid, with uniformly spaced dots, each representing a unit area according to the scale of the sketch, is placed over the sketch (or underneath if the sketch is drawn on transparent paper), and the number of dots lying inside the perimeter of the field is counted. When several dots lie on the sides of the field, only one out of two is counted. The total area is calculated by multiplying the number of points by the unit area.

277. The grid method is fairly rapid and does not require any special skill. However, it tires the enumerator's eyes who is liable then to miscount the number of squares or dots. To reduce that type of error, the counted squares, or dots are ticked one by one and every tenth is numbered. The degree of accuracy of this method can be quite good.

278. The most accurate instrument for measuring sketch areas is the polar planimeter when operated by experienced personnel. It is used when the shape is irregular and its function is to determine the size of areas (in units of wheel revolutions) with one simple tracing operation of the boundary. The planimeter is supported on the paper at three points: the anchor point or pole, the rotating wheel and the tracing point. The measurement is made by placing the tracing pin at a convenient point on the boundary of the area to be measured and recording the reading on the wheel (or better still, putting the wheel at the zero position). Then the tracing pin is carefully guided around the entire boundary of the area to the starting point and another reading is recorded. The difference between the two readings determine the size of the area. The average of several measurements may be used if more accuracy is desired. In general, good planimeters are rather costly instruments.

279. An order of magnitude of the area of a field can be quickly estimated and used to check gross errors of calculation (e.g. misplacing decimal point), when the perimeter

(length of the boundary) is known. This is done by dividing the perimeter by a number between 4 and 5 and squaring the result. The choice of the divisor is subjective and is based on the degree of complexity of the boundary: number of sides, number of concavities, etc. Thus, if the field is very complicated the divisor should be nearer to 5 and of almost a square or rectangle nearer to 4. For example, the polygon in Figure 6a has four sides and no concavities, the divisor is 4.4; in Figure 6b, where the number of sides is six and one concavity, the divisor is 4.6, and in Figure 6c, where the number of sides is twelve and three concavities, the divisor is 4.8. The divisor might exceed five when the figure is very complicated.

280. When the direct triangulation of the crop area is feasible in the field, (cf. paragraph 272), there is no need to draw a sketch of the parcel. The area can be calculated directly from the actual field measurements using the same formula as in paragraph 272. The formula can be easily programmed on any programmable pocket calculator.

281. With the present developments in programmable pocket calculators and the relatively low cost of such instruments, most of the above-mentioned techniques for evaluating crop areas have become obsolete. In fact, given the measurements of sides and bearings of any polygon, programmes can be prepared for these instruments, to:

- estimate the closing error
- adjust sides and/or angles according to any desirable instructions to close the polygon, and
- calculate the thus closed area.

The total operation requires from 2 to 5 minutes per parcel or field. The instructions for the use of the calculator are quite simple and require very little training to be mastered.

282. The FAO has prepared such programmes together with the mode of operation for a large number of the presently available pocket calculators. They cover the following makes and models:

Hewlett Packard	- HP-25/25C HP-29C HP-55 HP-65 HP-67
Texas Instruments	- SR-52 SR-56 T1-58/59 and T1-58C/59C
Casio	- fx-201P fx-501P/502P

Programmes for the estimation of area through measurements of lengths and bearings of the sides using programmable pocket calculators and instructions were prepared by Mr. P. Petricevič.

CHAPTER IV. MEASURING CROP YIELDS

Introduction

283. The traditional way of collecting yield statistics is through reporting services, consisting either of extension work agents or the cultivators themselves. In many countries which do not yet have the facilities needed for establishing reporting services, the use of objective methods, in one form or another, seems to be a safe way of rapidly establishing a satisfactory system of yield statistics. By means of a sampling procedure, small plots of a crop are selected, the crop on these plots is then harvested, threshed, weighed and the yield estimated.

284. The simplest and most precise objective method for the estimation of the yield is to select a random sample of the fields of the crop under investigation. The crop is harvested, threshed, dried and/or otherwise processed, and the produce weighed and the yield is estimated by dividing the production by the net area of the sample fields. Such a method eliminates most of the random errors and biases involved in the selection of the sample plot within the field, its size and shape, the border effect, etc. Moreover, the resulting estimate represents the economic yield since harvest and post-harvest losses have not been taken into account. This method is useful, especially for small size fields, whenever it is feasible.

285. In the now classical procedure of crop-cutting plots for the objective estimation of crop yields, the following operations are carried out:

- selecting the sample fields;
- locating the sample plots within the fields;
- measuring the crop density (optional);
- harvesting and processing the crop;
- weighing the produce at different stages, and
- estimating the yield.

Each of these operations presents specific problems and decisions have to be taken on the method or technique to be utilized. Also, some operations may necessitate use of special instruments. In what follows, the different operations are reviewed; the problems are explained and proposed solutions given; and the crop-cutting and weighing instruments are assessed. The methods of statistical estimation of the yield belong to the theory of sampling and are not discussed in the manual.

Office and Field Operations

Selection of sample fields

286. Sample surveys of yield based on crop-cutting are normally carried out on only one crop. This is so primarily because different crops have different maturing periods and, therefore, are harvested at different times and crop-cutting has to coincide with the harvest. In this situation a rigorous application of the principles of random selection could be carried out in one of the following ways:

287. If cadastral maps are available, area units of some kind can be constructed and selected in the first stage. These selected areas can then be checked with the map in hand

and a list of fields under the crop involved can be prepared. This operation produces results which makes random selection possible as all the second-stage units will be known. However, the procedure may become costly. In addition, most of the cadastral maps may not be up-to-date and would have to be adjusted in the course of the field work. This introduces further complications.

288. If no cadastral maps are available, sketches may be prepared for some area units. A sample of these units is selected at the first stage of selection. The selected units may be segmented into a number of smaller area units. A sample of the latter is selected and the listing of fields growing the crop concerned is carried out in the selected segments only. A sample of fields is finally selected for the crop-cutting work.

289. Although the introduction of an additional stage of selection increases the variance, it does not lead to great difficulties as experience has shown that yield surveys can be carried out with three to five stages of selection without running the risk of excessively large samples. The difficulty lies again in the cost. The listing of fields under some specified crop may make yield surveys an impossible task in some countries. Another difficulty concerns the sketches: their preparation may present a very serious problem in terms of funds and skill needed to prepare accurate sketches.

290 Another possibility is to select villages or some other convenient area units in the first stage of selection and then list all the agricultural holdings which grow the crop concerned and are located within the boundaries of the selected villages. In the course of listing, it is advisable to collect for each holding information on the number, name and location of each field growing the crop involved. With the prepared list, a sample of holdings is selected and then a sample of fields within the holdings selected.

291. This procedure has been frequently used if no alternatives are available for the construction of the frame except a list of villages. The main problem of the procedure is the cost of listing the holdings. Another problem concerns the quality of the information on the fields growing the crop as provided by the farmers.

292. The application of the procedures listed follow strictly the principles of random selection and some difficulties encountered in their application may be found excessive. For this reason, recourse is often made to simplified procedures and to deviate from strictly random selection. There are alternative procedures that may be tried. One is called the cruising technique. With this technique a sample of villages from certain suitable area units is selected. The enumerators then drive, ride or walk along roads traversing agricultural areas near these villages and stopping at equal intervals. The field which bears the crop and lies nearest the road is selected. It is obvious that with this technique all the fields growing the crop under the sample area do not have the same probability of selection. Those which are far from the road have no chance of being selected. If these are different from those along the road the estimates of yield will be biased.

293. The following is another simple procedure. A sample of households or holdings is sometimes selected and those which are in the sample are then visited and asked whether the crop concerned is grown and also the number of fields with such a crop. A field is then selected at random from the fields with the particular crop for further work.

If there is no field with that crop, the selected household is substituted by the nearest household and the same operation is repeated. Such a procedure has a number of inconveniences and problems. If the list of holdings is used, many of them may have to be visited before the requisite number of fields has been selected. The other problem concerns the quality of the list of households or holdings. The fields belonging to holders residing in cities or outside the villages concerned have no chance of being selected. Another difficulty may be connected with the weighting procedure. Since only one field is selected from each household growing the crop, unequal probabilities will be introduced into the selection of fields. This calls for appropriate weighting in the estimation procedure which is not advisable.

294. Many different types of deviation from random selection of fields are possible but they might introduce unknown biases in the survey results. For this reason it is useful to provide in the survey report any information on the method of selection of fields that may help users of data to appraise the quality of estimates.

Location of the sample plot within the field

295. The term "sample plot" refers to a small area of the field where the crop will be cut or harvested for the purpose of the survey and taken for threshing, drying or otherwise processing and weighing. Following the principles of the sampling theory, the fields selected are divided into plots in such a manner that each point of the field belongs to only one plot. The requisite number of such plots is then selected to comprise the sample. To simplify survey practice, sample plots are made of equal size. Otherwise a complex weighting system is needed in the course of the estimation procedure.

296. These sampling theory principles can easily be applied if the fields are of convenient shape. For example, if the field selected is rectangular with sides of dimensions "a" and "c" metres and the plot consists of a square the side of which "s" is a common sub-multiple of "a" and "c", i.e. $a=ks$ and $c=ls$ where k and l are integers, the field is considered as consisting of square plots arranged adjacent to each other in "k" rows and "l" columns. Sampling then entails random selection from these plots. Similarly, if "l" is a sub-multiple of the length "a" of the rectangular field, i.e. $a=k_1 l$ and "w" a sub-multiple of its width "c", i.e. $c=k_2 w$ where k_1 and k_2 are integers, the field can be divided into $k_1 . k_2$ rectangular plots. Random selection from these plots is also feasible.

297. The shapes of fields, however, are often irregular and such a selection procedure does not result in an unbiased sample of area. Figure 10 will clarify the point. The thick line on this figure indicates the border of a field of irregular shape. The thin lines represent grid consisting of plots of one square metre each, from which a random sample of plots is to be selected. The shaded area represents the plots cut by the borders of the field. If one of these plots is selected and kept in the sample, a problem of estimation will arise. Namely, since all the plots in the sample will not have the same area, weighting will be needed in the estimation procedure. Since this is generally unacceptable on the grounds of computational complications, such plots are either rejected or the plot's frames pulled inside the field so that their whole area is located within the boundaries of the field. The consequence of the rejection is obvious: the shaded area of the field has no chance of being included in the sample. On the other hand, if plot's frames are pulled inside, this means that a belt of the area along the shaded borders of the field has a higher probability of selection than the rest of the field.

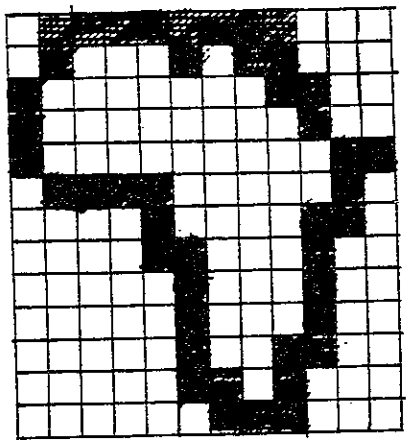


Fig. 10 Border bias.

If the yield along the border is different from that of the remaining parts, both these procedures will lead to a bias in the estimates of the yield. This bias is associated with the borders of fields and is, therefore, given the name of border bias.

298. If it is assumed that the yield is distributed at random over the whole area of the field, the practice of yield surveys can be greatly simplified. Namely, in order to get the coordinates of the corner or the centre of sample plots with such an assumption, it is sufficient to walk (approximately) along the longest diagonal and stop at (approximately) equal intervals, the number of which depends upon the number of sample plots needed. Each stop is then used as a position for locating the plot.

299. Such a simplification is very often used in yield surveys. It has the obvious advantage of reducing the cost and amount of work. It makes unnecessary the measurement of the field, the selection of random numbers, measurements connected with the location of the points selected, etc. Its disadvantage lies in the fact that it becomes difficult to limit the arbitrariness of locating the plots by the field staff.

300. Another reason for the use of diagonal selection is that it reduces the damage to the crop in the course of the location of sample plots. The field staff will be obliged to walk over the whole field (provided several plots are selected from the same field) to locate the selected plots. This might displease the farmers with the result that the survey may not be carried out in all the fields selected. The location of plots along a diagonal seems to be a procedure which provokes less resistance on the part of farmers.

301. Another simple but subjective method to locate the crop-cutting plots in fields where the yield is highly variable is to ask the enumerators to select three patches of the field in which the crop yield was poor, average and good and to place one plot in each of these patches. Apart from the difficulty of eye estimating the quality of the crop all over

the field, which cannot be seen at a glance, the enumerator might be liable to select near-by patches, e.g. near the border of the field, thus increasing the border bias.

302. The methods currently used in many countries for the location of a reference point (the centre of one corner) of the crop cutting plot are based on the selection of two random numbers. These could be the cartesian coordinates of the random point or, more frequently, the first represents a random distance measured along the perimeter and the second a random distance measured along a straight line in a given direction within the field.

303. For locating the random reference point of the crop cutting plot, the instructions to be given to the enumerators could be similar to the following steps:

1. Measure the perimeter of the field in terms of number of paces;
2. Divide this number by 2 to get the semi-perimeter;
3. From the table of random numbers, select two numbers less than the semi-perimeter;
4. From a given fixed point (e.g. the south-west corner of the field), walk a number of paces along the perimeter in a clockwise direction, equal to the first random number selected;
5. At this point, enter the field in a direction perpendicular to the side of the field and walk a number of paces equal to the second random number. This will determine the reference point;
6. If the field is narrow and the second number of steps will get you outside the field, when you arrive at the border, turn around and walk in the opposite direction the complementary number of paces.

304. When the crop-cutting plot is a circle, the random reference point thus obtained is considered as its centre but when the plot is square or rectangular, the random point is taken to be one of the corners. In the latter case, the instructions to the enumerators are generally to lay the diagonal of the plot beyond that point and in the same direction as that of walking and to construct the plot around it.

305. If, by so doing, the crop-cutting plot crosses the border of the field, two procedures have been used:

1. the plot was rejected, two new random numbers were selected and the whole operation repeated, and

2. the plot frame was pulled in so that the end of the diagonal lay on the border.

Border bias

306. In both procedures, points near the border of the field will have a probability P_B of being included in a crop-cutting plot different from the corresponding probability P_I of points in the inner part of the field (cf. para. 308). The problem is to compare these two probabilities and evaluate their ratio $\frac{P_B}{P_I}$ in both the cases where the random plots crossing the border of the field are rejected and where the random plots are pulled in.

307. In order to illustrate the two situations, consider the field TVXYZ and its inner part T'V'X'Y'Z' (Figs. 11a and 11b). Assume that the first random number (to be taken on the perimeter of the field) determines a point P somewhere on its side VX; that the direction of walking inside the field is perpendicular to VX and upwards (towards YZT) and that the second random number is smaller than the width of the field measured at P. The random reference point of the crop-cutting plot will be inside the field and the diagonal is to be placed above this point, towards YZT and perpendicular to VX.

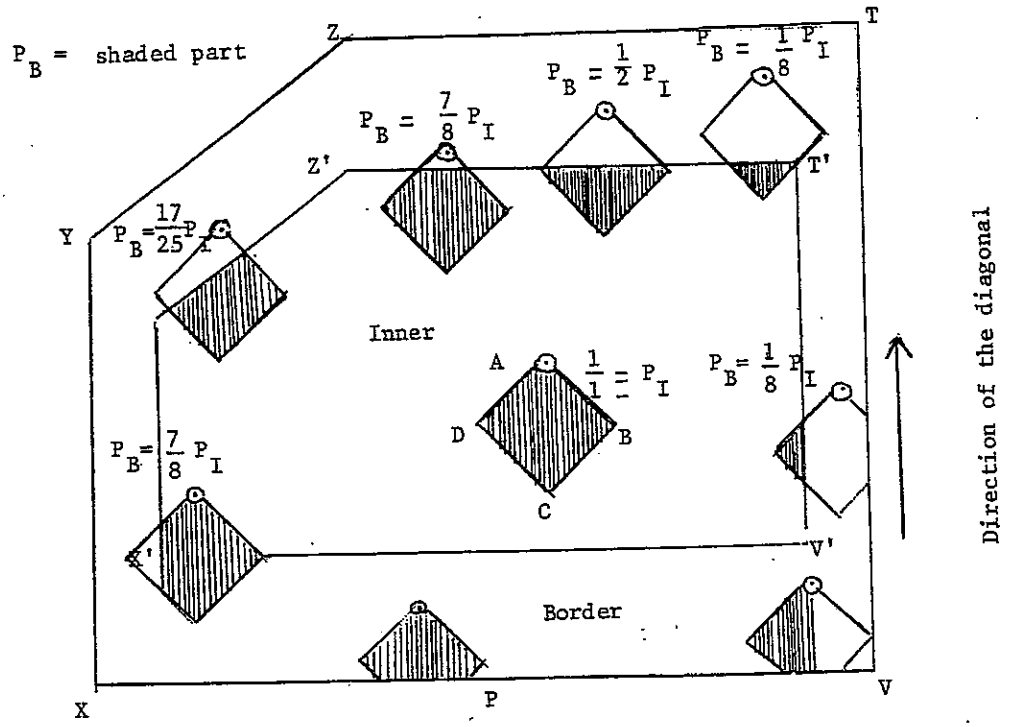


Fig. 11a. Border bias. Value of $\frac{P_B}{P_I}$ when border plots are rejected.

308. In the case where the crop-cutting square plots frame crossing the border are rejected, the probability for any point A within the field to be included in a random crop-cutting plot is proportional to the subset of the field's points which have the property that the crop-cutting square built above them includes the point A and that the square lies completely within the field. These subsets of points are represented by the shaded parts in Fig. 11a where the point A under consideration is the circled point at the top of the squares.

309. In the case where the crop-cutting square plots frame crossing the border are pulled in, and for points A in the border fringe (area bounded by TVXYZ and T'V'X'Y'Z'), to the subset defined in para. must be added another subset of points, namely those for which the pulled in crop-cutting square frame includes the point A (the shaded parts in Fig. 11b). This second subset in a rectangular set of points of the border.

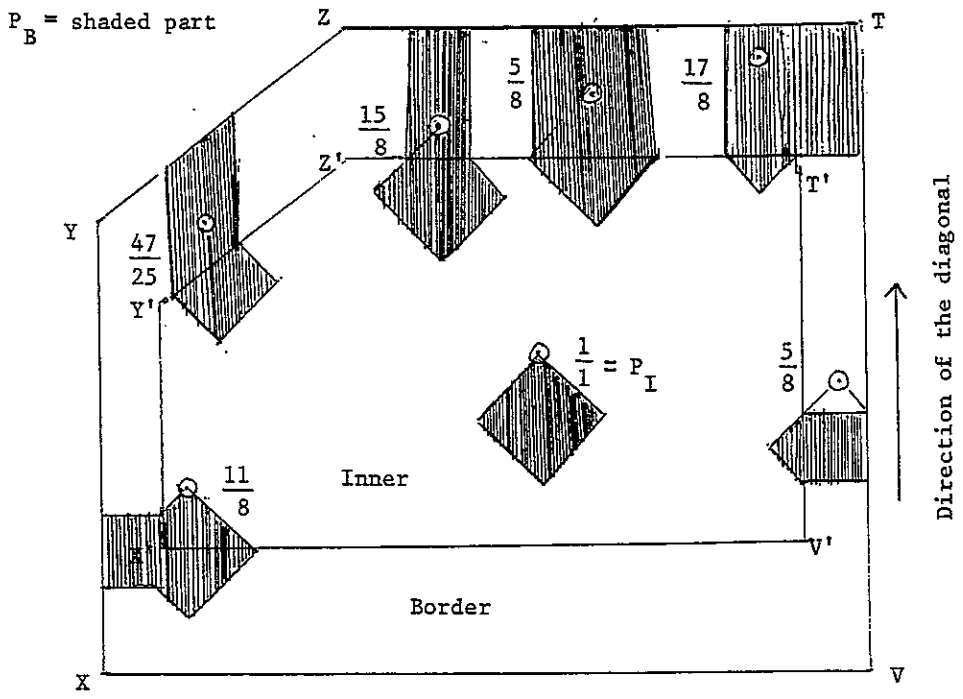


Fig. 11b. Border bias.

Value of $\frac{P_B}{P_I}$ when border plots frame are pulled in.

310. Thus, the probability that an interior point (in T'V'X'Y'Z') is included in a crop-cutting square plot is proportional to the area of the square and will be denoted hereafter by P_I. This is not the case for a strip bordering the field, the width of which is equal to "D" the diagonal of the crop-cutting square, the probability of inclusion of a point A of the border is then proportional to $P_B \neq P_I$ and depends on its position and on the procedure followed in dealing with plots crossing the border of the field.

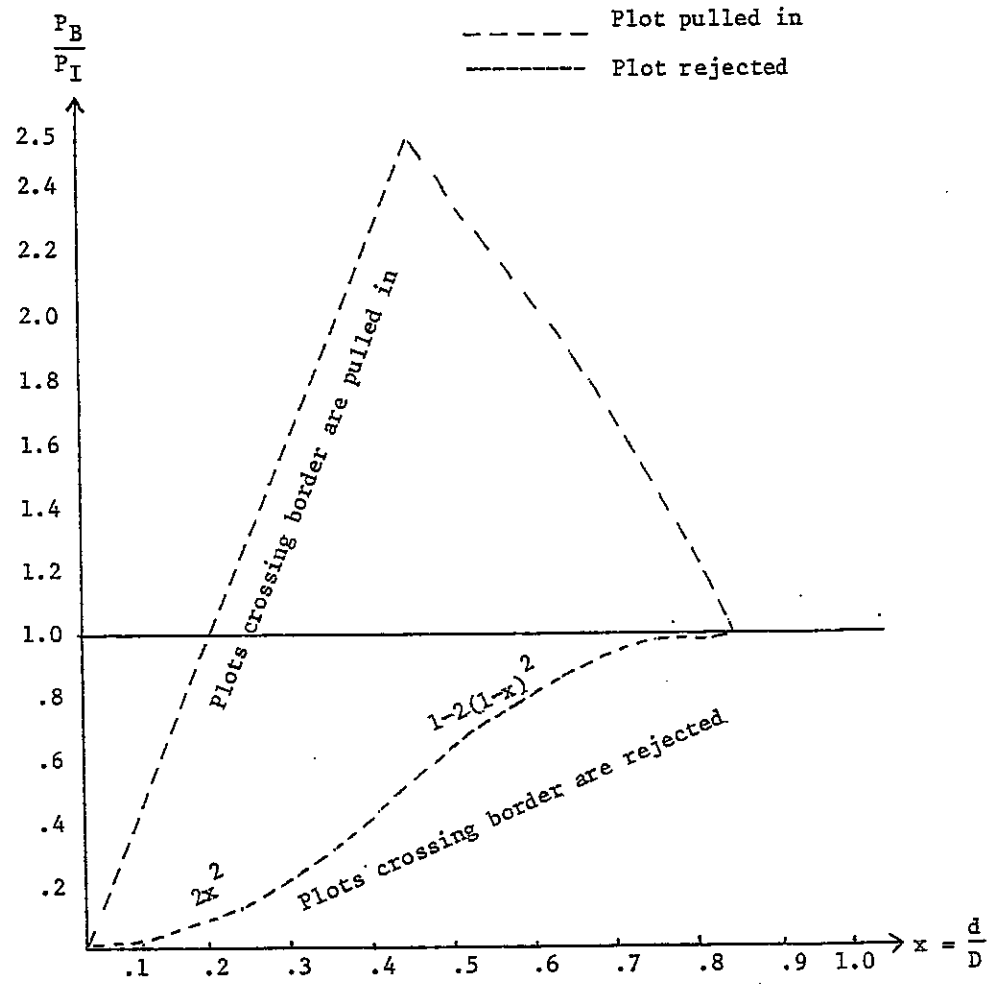
311. When the procedure is to reject such plots and to start all over again, the probability that points in the border fringe of the field are proportional to P_B, that part of the area of the square which falls within the inner part of the field (the shaded parts in Fig. 11a). Thus P_B is less than P_I and points in the fringe will be under-represented in the crop-cutting operations. More precisely: let "d" be the distance of the point from the border of the field and "D" the diagonal of the crop-cutting square, and let $x = \frac{d}{D} \leq 1$, then it is easy to show that the ratio

$$\frac{P_B}{P_I} = \frac{\text{Probability of a border point}}{\text{Probability of an inner point}}$$

can be expressed as a function of "x" as follows:

$$\frac{P_B}{P_I} = \begin{cases} 2x^2 \text{ for } 0 \leq x \leq \frac{1}{2} \\ 1-2(1-x)^2 \text{ for } \frac{1}{2} \leq x \leq 1 \end{cases}$$

This function is plotted as the lower curve in Graph I below.



Graph I. Border bias.
Value of $\frac{P_B}{P_I}$ as a function of $x = \frac{d}{D}$.

312. When the procedure is to pull the plot frame in so that it lies completely within the field, the probability that the point is included in the crop-cutting is increased by an amount proportional to a rectangular area depending on its distance from the border (shaded parts of Fig. 11b give the values of P_B in this case). More precisely, using the same notation as in paragraph 311 it is easy to show that

$$\frac{P_B}{P_I} = \begin{cases} 2x^2+4x & \text{for } 0 \leq x \leq \frac{1}{2} \\ 3 - 2x^2 & \text{for } \frac{1}{2} \leq x \leq 1 \end{cases}$$

This function is plotted as the upper curve in Graph I.

313. If the crop yield conditions in the fringe of the field are significantly different from those of the inner part, the bias introduced by neglecting the crop-cutting plots which cross the border is smaller than the bias resulting from pulling in the plot as can be calculated using the formulae of paragraphs 311 and 312 (cf. Table 6) and directly seen from Graph I. For this reason it is recommended to use the former procedure.

Table 6. Border bias

Value of P_B / P_I

$x = \frac{d}{D}$	$\frac{P_B}{P_I}$	
	Border Plot Rejected	Border Plot Frame Pulled in
0.1	.02	.42
0.2	.08	.88
0.3	.18	1.38
0.4	.32	1.92
0.5	.50	2.50
0.6	.68	2.28
0.7	.82	2.02
0.8	.92	1.72
0.9	.98	1.38
1.0	1.00	1.00

Crop planted in rows.

314. The procedure of entering the field and placing the crop-cutting plot proposed in paragraph 303 can be improved when the crop is planted in rows. The improvement consists in the reduction of the variability of the number of plants and consequently of the variability of the yield between the crop-cutting plots. When the crop-cutting plot is a circle no improvement is possible but in all other cases (square, rectangle, etc.) alternative procedures can be used to reduce the variability. Some of these procedures are given hereafter.

315. In the first proposed procedure, the six steps (paragraph 303) to be carried-out by

the enumerator to locate the random reference point are not altered but the instruction in paragraph 304 on the method of laying the diagonal is modified into "lay the diagonal of the crop-cutting plot in a direction parallel to the crop rows".

316. The second procedure relates to the method of entering the field (step 5 of paragraph 303). Instead of entering the field in a direction perpendicular to the side of the field, the instruction is modified into "enter the field in a direction parallel to the direction of the crop rows". The instruction of laying the diagonal in the same direction as that of walking (paragraph 304) is not changed. It is obvious that the two procedures produce crop-cutting plots of the same configuration.

317. In order to illustrate the reduction in the variability of either the number of plants or the total length of lines included within the crop-cutting plot, the above-mentioned procedures (Figs. 12a and 12b) are compared with the procedure in which the crop-cutting square or rectangle is so placed as to have its sides parallel and perpendicular to the direction of the crop rows (Figs. 13a and 13b). In both cases, the number of rows which cross the plot, (a segment of the row is included in the plot) may differ by one unit according to the position of the random reference point (its distance from the crop row) except in the case where the diagonal in the first case and the side of the plot in the second case is a multiple of the distance between crop rows.

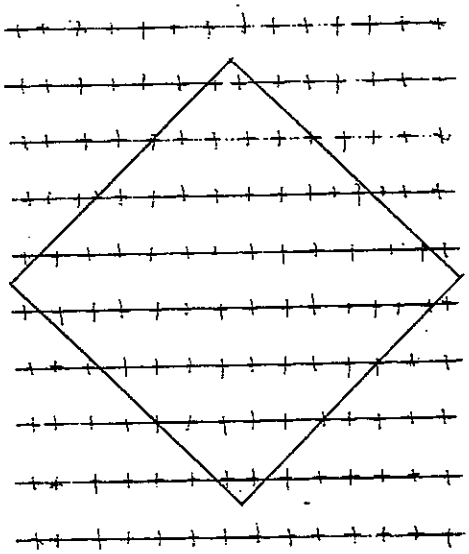


Fig. 12a

Side = 5.00m
Diagonal = 7.07m
Distance between rows = 0.90m

Number of crop rows = 7
Length of crop rows = 27.83m

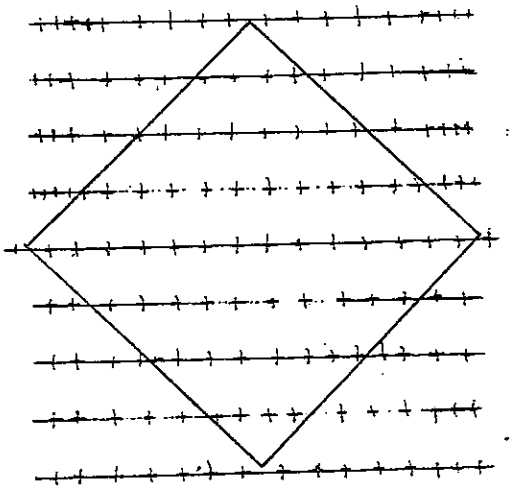
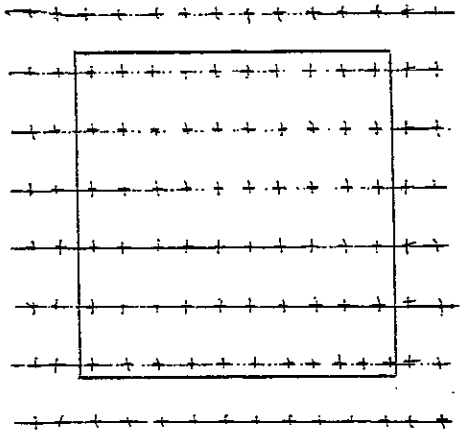


Fig. 12b

Number of crop rows = 8
Length of crop rows = 27.77m

318. In the illustration it is assumed that the crop-cutting plot is a square of side equal to 5 metres and that the distance between crop rows can be anything between 10 cm and 2 m (in Figs. 12a, 12b, 13a and 13b, the distance is supposed to be 90 cm).



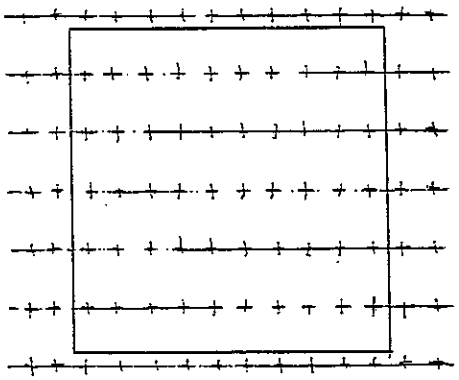


Fig. 13a — Side = 5.00 m. — Fig. 13b

Distance between rows = 0.90 m

Number of crop rows = 6
Length of crop rows = 30.00m

Number of crop rows = 5
Length of crop rows = 25.00m

319. It is obvious that, in the case where the side of the crop-cutting square is parallel to the crop rows, a difference of one row means that the total length of crop lines within the plot differs by the length of one row (5m). In fact, in the example shown in Figs. 13a and 13b, the total length is either 30m or 25m according to the position of the square. This is not the case when the diagonal is parallel to the crop rows and the length of a crop line varies according to its position within the plot. Here, some compensation takes place and the range of variation is quite narrow. This can be seen from Table 7 which gives the range of variation of the total length of crop lines included in the crop-cutting plot for different values of the spacing of the rows of plants.

320. Another alternative procedure is based on a rectangular crop-cutting plot of partially flexible size: the length is pre-determined while the width depends on the spacing between the crop rows and has to be measured accurately. In this procedure:

1. the reference point (one of the corners of the rectangle) is moved from its random position to the nearest point "A" at equal distance from two crop rows;
2. the pre-determined length AB is laid parallel to the crop rows;
3. an arbitrary number "n" of successive crop rows is taken to be included in the rectangular plot;
4. when the spacing is uniform, the width will be equal to "n" times this spacing and thus the side CD of the rectangle will be parallel to the crop rows and at equal distance from the "nth and (n+1)th rows.

Table 7. Variability of Crop Yields due to Position of Crop-Cutting Plot 5m x 5m

Distance Between Crop Rows	Diagonal Parallel to Crop Rows		Side Parallel to Crop Rows	
	Number of Lines	Range of Total Length (in metres)	Number of Lines	Range of Total Length (in metres)
10 cm	70 or 71	249.97 - 250.04	50	250
30 cm	23 or 24	83.31 - 83.43	16 or 17	80 or 85
50 cm	14 or 15	49.99 - 50.07	10	50
70 cm	10 or 11	35.71 - 35.78	7 or 8	35 or 40
90 cm	7 or 8	27.77 - 27.90	5 or 6	25 or 30
100 cm	7 or 8	24.57 - 25.50	5	25
150 cm	4 or 5	16.28 - 17.36	3 or 4	15 or 20
200 cm	3 or 4	12.28 - 13.21	2 or 3	10 or 15

321. Figure 14 illustrates such a case. The length AB of the rectangle is taken to be 6m; the regular spacing of the rows is 80 cm., the vertices A, B, C and D are distant 40 cm. from the crop rows, and the arbitrary number of rows within the rectangle is 7. Thus, the area of the rectangle is 7 x 6 m. x 0.80 m. = 33.6 m^2.

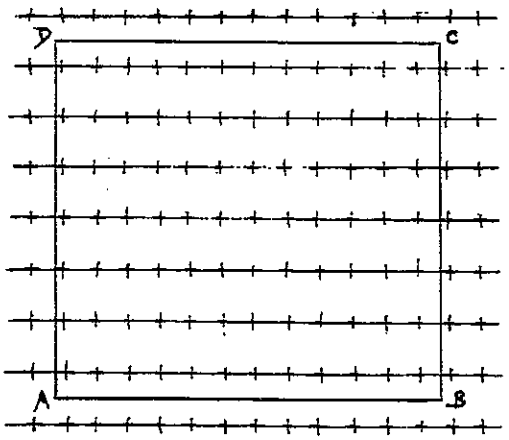


Fig. 14. Rectangular Plot with Flexible Area

322. Crop cultivation in rows makes it possible to estimate the yield by means of objective procedures without using sample plots. Plots are avoided if a sample of rows is selected first from sample fields and then the rows are sub-sampled by cutting the crop along a part of the row which is found to represent a convenient sampling unit. Such a procedure is recommended and can be applied even when the spacing between the crop rows is not uniform.

323. Crop-cutting plots are also avoided in the case of tree plantations (in rows, quincunx or haphazard) where the yield is no more the production per unit area but the production per tree. In this situation, the sampling of trees within the sample plantations can be either simple random or cluster sampling. In the latter case, a tree is randomly selected and then an appropriate number "n" of trees around and nearest to it constitute the sample.

Cutting the crop

324. In carrying out yield surveys there are two main approaches from the organizational point of view. The first consists in establishing a moving machinery of properly trained staff who are equipped with transport and everything else needed for the work. These moving teams visit the fields selected for the purpose of cutting the crop and to reach the field selected immediately before the harvest. The team might reach some fields just in time; on other fields the crop might not yet be ripe and the team might be obliged to cut it as it is because it is not normally possible to go back to the same fields a second time. In some cases, however, the harvest might already be over when the team reaches the selected field.

325. If a team is responsible for a large area it will hardly be possible to arrange this work in such a way that no sample field is harvested before the team arrives. The problem, however, is overcome by the approach based on the cooperation of some local staff who get in touch with farmers to find out the harvesting day. In this case the crop-cutting is always done immediately before the harvest and missing information is avoided.

326. In some countries it may be useful to proceed in two stages. In the first stage the field is selected and, in agreement with the farmers concerned, the position of the sample plot is marked. Afterwards the field staff should remain in contact with the farmers to secure the information about the day of the harvest. On the basis of this information the plots selected will be cut immediately before the harvest, preferably by the farmer himself. This arrangement is possible when a team is responsible for an area. In some developing countries it may be found that some farmers will take more care of the crop-cutting plot than for the rest of the field and in some countries the farmers will try to reduce the yield either by neglecting the plot or harvesting a small part of the plot before the crop has matured.

327. It is useful also to count the number of plants (or hills, mounds, etc.) within the crop-cutting plot immediately after fixing the plot, especially in the case where it is fixed well in advance before harvest. The knowledge of the density of plants is a useful piece of information on its own but it can also be used to estimate the yield in the case of missing plots (or part of the plot); to estimate the amount of damage or loss in case of natural disasters; to allocate the areas of the different crops in mixed cropping, etc. Sometimes it is useful to count also the number of ears, cobs, bunches, etc., of the crop within the plot.

328. Another procedure that may be used to ensure that the crop is cut at the appropriate time and which has been used in some developing countries is based on the cruising technique. During the harvest period of the crop under consideration, a specific route (different every day) is assigned to a team of enumerators within the agricultural land of the village, and whenever the team comes across a field which is being harvested, they stop, place a random plot, crop cut, process and weigh the produce.

329. In the case when only the crop within the plot is to be harvested, a problem arises of what to do with plants which lie exactly on the boundary of the plot. One rule is to consider the bunches of tillers of the plant and separate carefully the tillers which lie inside from those which lie outside the plot, and only those inside the plot are to be harvested. In the case where this is not possible and no decision can be taken about including or excluding the plant, an alternative rule is to include and harvest one plant out of every two. These rules will reduce the bias in the results. Another useful alternative procedure is to start by harvesting the inner part of the plot and moving gradually towards the boundary. In this way the situation of the boundary plants will be clearer.

330. For underground crops like tubers, the crop-cutting plot can be defined according to what is meant by the crop inside the plot:

1. the plot is considered the physical land area and all the tubers which belong to the plant inside the plot are to be lifted whether they lie in the ground underneath the plot or not. Tubers which lie under the plot but belong to plants not included in the plot are not harvested;
2. the plot is considered to be the physical land area and all the tubers underneath the plot are to be lifted irrespective of the plants to which they belong.

Both concepts are valid but the first one is difficult to apply and is liable to risks of error or biases. For this reason, it is the second concept and method that is found useful.

331. Biases will appear in survey data if the harvesting procedure in the survey and in the actual harvest are not strictly comparable. The survey is to be conducted following the farmers own methods. The crop should be cut at the same time and in the same way as the farmers do. It should be threshed, dried and processed as the farmers do. It should be exposed to the same wastage, etc. By following these principles the expected biases in the results will be reduced.

332. Losses represent a big problem in yield surveys. If the crop is cut and the produce preserved so that no losses occur, the survey estimates refer to what is often called the "biological yield". The usual aim is to establish the "economic yield", i.e. the usable part of the biological yield, after allowing for wastage and losses. Yield surveys should show the quantity of the crop available to the farmer. Therefore, if waste is disregarded, the survey will overestimate the "economic yield". In estimating the waste it is obviously necessary to make sure that all types of waste (losses in the process of harvesting, in handling the produce, during transport, etc.) are covered from the moment of harvest until the crop is stored.

Plot Size and Shape

Plot size

333. The problem of how large the sample plot should be with different techniques and various crops has attracted the attention of many statisticians all over the world and particularly in India. This is not surprising. Various arbitrary factors in the location of a plot which can never be completely eliminated are likely to have a greater effect on the estimates based on small plots. On the other hand, on large plots more time is needed to cut the crop. They also present difficulties if the crop harvested is to be taken away for various purposes such as weighing or drying.

334. The arbitrariness in the location of plots would have no effect on the estimated yield if it were completely uninfluenced by patterns of selection. However, there is a serious danger that staff may try to avoid places of poor yield by preventing plot coordinates from falling there and may also try to apply their judgement with a view to locating plots on places typical of the field.

335. If any pattern of this type is practised by the field staff, then biases of undetermined magnitude are introduced. Furthermore, if field staff are not careful in including or excluding individual plants from the plot, the biases may be very important especially with small plots but may be negligible with large plots. Clearly then, it is important to study the question experimentally.

336. The question of the effect of the plot size on the estimated yield has been studied more systematically in India than in any other country. Two different groups of statisticians were mainly involved in this work, one working for the Indian Statistical Institute under the leadership of Mahalanobis and the other for the Indian Council of Agricultural Research under the guidance of Sukhatme.

337. In his early experiments with jute, Mahalanobis found that small plots might lead to biases because there is a kind of ".... psychological bias on the part of the investigator to include unduly some of the bordering plants or tillers inside a cut". The matter was studied experimentally in many surveys and the results obtained are presented here in Table 9 which refers to a large number of different sizes of plots and shows that serious overestimation appears with small plots. Mahalanobis himself admits that this could be considered the conclusion to be drawn from a large number of his experiments.

338. Sukhatme has presented results which show the same tendency of overestimation associated with small plots. An illustration of the magnitude of the bias that might appear with small plots is given in Table 8. Similar percentages of overestimation were obtained for both irrigated and non-irrigated fields. The percentages shown may be taken to represent biases because in the experiments conducted earlier by harvesting the whole field, it was found that the largest triangle in Table 9. gives unbiased estimates. It is believed that the bias is caused by a tendency on the part of the field staff to include some border plants inside the plot even if they should be excluded.

339. The same types of experiments were conducted in a large number of other surveys dealing with different crops and the same basic tendency of obtaining overestimation with small plots was found. The same problem was studied by Yates. In Yates' experiments a hoop of 10 square feet, a rectangular plot of 1/20 acre and the whole field were used.

A bias in estimates based on small plots was found and explained as resulting from a tendency on the part of the field staff to put the hoop on places of better yield.

Table 8. Mean Yield of Jute as Obtained from Plots of Different Sizes and Expressed in Percentages of the Largest Cut Size
(Bengal, 1939-40 to 1943-44)

Serial number	Size of sample cut in feet	Area in square feet	Mean yield expressed as percentage of the mean yield of the largest cut					
			Independent cuts			Nested cuts		
			1939-40	1942-43	1943-44	1939-40	1942-43	1943-44
1	1 x 1	1	-	-	-	162	-	-
2	11 x .5	5.5	149	-	-	-	-	-
3	3 x 3	9	-	119	-	104	114	-
4	11 x 1	11	109	-	-	-	-	-
5	5 x 3	15	-	-	-	-	112	-
6	4 x 4	16	-	-	113	-	-	99
7	7 x 3	21	-	-	-	-	106	-
8	11 x 2	22	88	-	-	-	-	-
9	5 x 5	25	-	99	-	-	98	-
10	11 x 3	33	101	-	-	-	-	-
11	7 x 5	35	-	-	-	-	98	-
12	12 x 4	48	-	-	-	96	-	-
13	7 x 7	49	-	110	-	-	97	-
14	8 x 8	64	-	93	101	-	105	101
15	11 x 6	66	100	-	-	-	-	-
16	12 x 12	144	-	87	94	100	100	103
17	15 x 15	225	-	100	-	-	100	-
18	16 x 16	256	-	-	88	100	-	101
19	20 x 20	400	-	-	-	-	-	100
20	24 x 24	576	-	-	100	-	-	-

Table 9. Overestimation of Yield with Small Plots

Sample of the plot	Area of the plot in square feet	Irrigated wheat		Non-irrigated wheat	
		Average yield in pounds per acre	Percentage over-estimation	Average yield in pounds per acre	Percentage over-estimation
Equilateral triangle	471.55	831.1	-	539.0	-
" "	117.89	870.6	4.8	598.2	11.0
" "	29.47	961.9	15.7	664.9	23.4
Circular	28.29	954.5	14.9	618.8	14.8
"	12.57	1 183.3	42.4	767.7	42.4

340. These experiences give rise to the question of what should be the size of plots in yield surveys. In line with his experiments, Mahalanobis' answer to this question is given in Table 10. In this table the plot of 100.9 square feet (about 10 m^2) is taken as standard and sizes of other plots are expressed as percentages. Larger plots than this require more time and are, therefore, rejected, while smaller plots require less time but are subject to bias. The plot size of 100.9 sq. ft. is the most economical size leading to unbiased estimates.

Table 10: Relative Efficiency of Sample Plots of Different Size

Size of the plot in sq. feet	No. of cuts needed for the same sampling error	Average number of hours of work needed to cut the crop	Total time needed	Total time as percentage of the standard
12.5	3.47	0.3	1.04	67
50.3	2.19	0.6	1.31	84
100.9	1.74	0.9	1.56	100
201.1	1.39	1.4	1.95	125
544.5	1.00	2.6	2.60	167

341. The present body of knowledge about these problems is too meagre to allow any generalization. It is important to point out that practice is very variable in this respect. In the yield surveys conducted under the auspices of the Indian Council of Agricultural Research large plots were used, ranging from 1/10 acre to 1/160 acre according to the crop and the size of the fields. In European countries, the United States, Japan, U.S.S.R., etc., it appears that very small plots prevail. Their size is around one square metre. The borders of such small plots are in many cases demarcated by placing a rigid portable frame. This is obviously an advantage because less time is needed to decide which crop falls inside and has to be cut. In addition, if the crop cut is to be taken away for various analyses, this is no problem with plots of a square metre even if the field operator has to walk a certain distance.

342. The above discussion of plot size dealt exclusively with the existence and magnitude of the bias in crop-cutting surveys. Another important aspect to be considered is the precision of the results. It is obvious that a small plot which contains a small number of plants will give less precise results than a larger plot which covers a larger number of plants. For this reason, a discussion on the size of the plot which ignores the type and density of the crop in the field would be incomplete.

343. The variability of the yield per plant within the same field is generally low and, if measured, could determine the optimum size of the plot from the point of view of precision of the results. For example, if the coefficient of variation of the yield per plant is of the order of magnitude of 0.20 (a reasonable estimate for many crops) a plot size which would cover about one hundred plants would reduce the coefficient of variation to about 0.02 (if all plots contained 100 plants).

344. Thus, the size of the crop-cutting plot is a function of the density of the crop within the field. For the very dense irrigated wheat, rice, etc., the plot size could be

quite small 1-5 m^2. For more widely spaced crops like maize, tubers, etc., the plot size could be larger 10-25 m^2. While, for very widely spaced crops and in the case of mixed cropping, the plot size could be as large as 100 m^2. In fact, in many developing countries in Africa, the plot sizes used were squares of 2 x 2m., 5 x 5m. and 10 x 10m. according to the type and density of the crops. Moreover, in order to get an estimate to the variation of the crop yield within the same field, two crop-cutting plots per field were placed.

Plot shape

345. Certain standard shapes of plots have been used in yield surveys based on crop-cutting. The most common ones are square, circular, rectangular and triangular. One of the objectives of crop-cutting surveys is to know whether the shape of cuts has any effect on the results collected. It can be seen from Table 10 that circular and triangular plots of approximately the same size gave yields which were very similar for irrigated wheat and considerably different for non-irrigated yield. However, these differences were not significant.

346. Mahalanobis and Sengupta have also studied this problem by using differently shaped plots of approximately the same size and comparing the yields obtained. The results found are presented in Table 11. Among the shapes listed in the first column "fork" is also found (cf. para.354). This is a rigid tool in the shape of a fork with two parallel prongs. The yield obtained for each size is expressed in percentages of the yield obtained with the circular plot. It follows from this table that a triangular shape may produce biased results.

Table 11. Difference in the Yield Obtained by Using Differently Shaped Plots of Approximately the Same Size

Shape (each 12.5 sq.ft.)	Average yield expressed in percentages of the average yield of the circular cut			
	Gouripur	Katwa	Sainthia	Combined
Circular	100.0	100.0	100.0	100.0
Triangular	115.8	125.0	123.2	123.5
Square	93.0	109.3	107.9	103.5
Fork	91.1	100.4	108.8	103.5

347. It must also be added that comparisons between the various shapes have to take into account the method of demarcating the plot. If it is found that a shape of a square metre marked in the field by means of a rigid frame and a corresponding metallic hoop do not yield significantly different results, it cannot be concluded that the same will apply to square plots marked with the help of pegs, string, measuring tapes and cross-staffs.

348. Biases due to plot shape have been attributed partly to the fact that enumerators are liable to include, in the crop-cutting plot, plants on the boundary which should have been excluded. On that basis, it was suggested to utilize plots with the smallest perimeter for the same size namely circular and square plots. Moreover, the instructions given in para. 329 concerning crop-cutting only those plants or tillers which lie within the plot and in case of doubt to crop-cut one of every two, should be strictly followed by the enumerators.

349. The problem of the size and shape of plots must be considered not only from the point of view of possible errors and biases but also from that of practical convenience. Excellent tools for experimental work may not be applicable in large-scale yield surveys. Moreover, these errors and biases may be small in comparison with other sampling and non-sampling errors due to the method of conducting the survey, the selection of the units and the crop-cutting procedure.

Crop-Cutting Equipment

350. Since it is necessary that the enumerators reach the fields selected for crop-cutting immediately before harvest and since it may happen that more than one sample field, in the assignment area of the enumerator, is to be harvested on the same day, it is essential that the enumerators be equipped with rapid transport facilities. In some developing countries, it was possible for the enumerators to utilize bicycles while in others it was necessary to provide them with motor cycles or even with motor cars.

351. For the location of the random reference point of the crop-cutting plot, the basic instrument is a table of random numbers. The enumerator is to be instructed on the use of the numbers in the table in a pre-established order for the selection of a pair of numbers for each random point. It is useful, for control purposes, that the pair of numbers selected be recorded on the crop-cutting form (questionnaire) and also that they be ticked-off in the table in order to avoid repeating numbers already used.

352. For measuring the distances along the boundary and inside the field, distances represented by the pair of random numbers, any one of the instruments described in Chapter III, e.g. tapes, measuring wheel can be used. However, as already mentioned, exact measurements are not essential and pacing may give unbiased results as long as the enumerator does not purposively enlarge or reduce the pace to arrive at a particular point within the field. For entering the field in the pre-established direction, an instrument for measuring bearings, e.g. a compass or a cross-staff,can be used. Here again accurate bearings are not essential and eye estimation of the direction of walking can be sufficient.

353. For the delimitation of the crop-cutting plot, different types of instruments have been used in developed and developing countries. The choice of the appropriate instrument depends on the size of the plot (small or large), the planting technique (haphazard or in rows), the period of delimitation of the plot (at the time of harvest or long before) and naturally the cost of the equipment.

354. In most developed countries, the crop-cutting plots are generally of a very small size: 1 to 2 square metres or yards and they are circular, square or rectangular. The instruments used is a rigid hoop for circular plots or a rigid square frame. When the crop is planted in rows, the fork is very often used (see para. 346). This is to be placed midway between and parallel to the crop rows. The lateral sides have graduated grooves on which is adjusted the rectangle's fourth side, a rod which should be parallel and at equal distance between two crop rows. The graduations on the lateral sides determine the size of the crop-cutting plot.

355. Another instrument used in many Asian countries for delimitating and crop-cutting circular plots is composed of a pole to be placed vertically at the random reference point and to which is hinged a rotating arm. To the end of the arm is attached a stylus to indicate the plants to be cut. The rotating arm can be adjusted to several fixed lengths (1 to 2 m.) so that circular plots of different radii can be used if desired.

356. In those developing countries where crops are planted haphazardly or where mixed cropping is practised, crop-cutting plots have to be quite large (e.g. from 20 to 200 m^2) and the above described methods are not applicable. Plots are generally square or rectangular in shape and marked with the help of pegs, measuring tapes or standardized cord, string or wire. Generally, this instrument, which can be constructed by the enumerators themselves

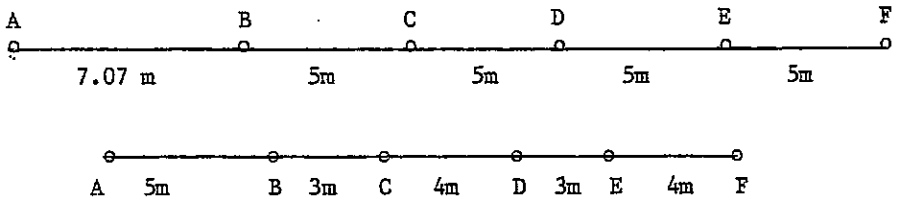


Fig. 15. Standardized cords

using non-extensible cord or string, is composed of 5 pieces joined together and ending with rings. The lengths of the pieces are in order: the diagonal of the plot followed by the 4 sides of the square or rectangle. For example, for a square of 5m x 5m, the cord ABCDEF is composed of AB = 7.07m and BC = CD = DE = EF = 5m, while for a rectangle of 3m x 4m, the cord ABCDEF is such that AB = 5m, BC = DE = 3m and CD = EF = 4m (cf. Fig. 15).

357. For placing the plot, the following operations are to be carried out:

1. a peg is placed at X the random reference point and around it is placed the ring A;
2. along the walking direction the diagonal AB is measured, a peg is placed at its end Y and the ring B is placed around it;
3. the ring D is placed around the peg at X and the ring F around the peg at Y;
4. the two rings C and E are successively pulled out on either side of AB and stretched in such a way as to produce the 2 right angles at C and E where pegs are to be placed and around which the rings at C and E are to be placed.

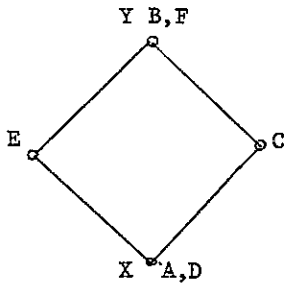


Fig. 16. Placing the plot

and thus delimitate the required square or rectangle (cf. Fig. 16).

358. Generally, three kinds of equipment are potentially available for weighting the produce of the plot. They are spring balances, scales using separate weights and roman balances. The advantages of spring balances are that they are portable, low cost and readily obtainable

in various sizes. Their disadvantages are that they are not a precision instrument and that they are capable of producing considerable errors, particularly after some time of use and also if ill-used. If used, they should be treated carefully and checked regularly.

359. The ideal equipment for crop weighing in crop-cutting surveys is the roman balance or steelyard. It consists of a lever with unequal arms, which moves on a fulcrum; the crop to be weighed is suspended or placed on a tray at the shorter arm, and a counterpoise is caused to slide upon the longer arm until equilibrium is provided, its place on this arm which is notched and graduated showing the weight.. Roman balances used by the FAO have two positions: in the first, weights up to 7 kilogrammes can be measured with a precision of 50 grammes and, in the second, weights from 7 to 30 kg. can be measured with a precision of 200 gr. Roman balances are sturdy instruments, their life is long and they are not very expensive, however, they are heavy and not particularly easy to transport.

360. Other equipment to be provided to the field staff consists of:

- a piece of cloth on which to spread the produce
- a pair of scissors, knife or hatchet for clipping or cutting the plants
- a wooden rod to thresh the produce and flat winnowers to winnow it
- strong cloth bags to despatch the harvested material or to store the totality or a sample of the produce
- tags to identify the field, the plot, etc.
- forms on which to record the data.

CHAPTER V. SPECIAL PROBLEMS

Shifting Cultivation

361. Shifting cultivation is defined broadly as a system under which crops are cultivated for a few years on a certain area of land, after which that area is abandoned temporarily and another piece of land cultivated. The abandoned land will be re-cultivated after its fertility is judged to be restored, or sooner if other land is not available for use.

362. As defined above, shifting cultivation covers the rotation systems which include a period of fallow and is not confined to tropical soils nor to developing countries. A system of abandonment of the land to rest or fallow is widely practised throughout the world and is an essential response to the problem of soils incapable of sustaining the continuous production of crops for an unlimited period.

363. However, it has been suggested that the term shifting cultivation be limited to the primitive practises of "slash-and-burn" where the farmers clear a wooded area (bush or forest) and cultivate it from 2 to 5 years to apparent exhaustion, then move to another area where the land appears to be in good condition and return back to the first area only after a longer period of time. (5 to 20 years)

364. Thus, the concept of shifting cultivation is based on a land-use time criterion which could be the indicator $I = \frac{C}{F+C}$ (cf para.369-370) where C is the length of the period of time (number of years) where the land is continuously cultivated and F the period of fallow or land abandonment within the time reference period (F+C) years. An arbitrary cutting off point is to be agreed upon. This could be: equal periods of cropping and fallow. Then, if the indicator I is included between $\frac{1}{2}$ and 1, the system of cultivation can be considered as permanent while the term shifting cultivation will be restricted to the cases where the indicator I is smaller than 1/2. Table 12, [16.17] shows the average value of this land-use indicator over the different areas considered to be under shifting cultivation in a number of countries in Africa and Latin America.

Table 12. Land-Use Indicator

Country	Average over Region $I = \frac{C}{F+C}$
Congo, P.R.	.34
Benin	.23
Liberia	.27
Malawi	.20
Mexico	.40
Niger	.50
Peru	.45
Uganda	.32
Venezuela	.44
Zaire	.17
Zambia	.25

365. In the collection of agricultural statistics, the problems encountered are those related to:

- the applicability of the FAO concepts and definitions of crop areas to the system of shifting cultivation;
- the estimation of the extent and nature of shifting cultivation in developing countries;
- the measurement of crop areas;
- the estimation of the decrease of the yield from year to year as the soil fertility is depleted;
- the concept of productivity of the land.

366. In the programmes for the World Census of Agricultural (WCA), the concept of total areas of the holding covers not only crop areas but also uncultivated land: fallow, natural permanent meadows and pastures; forest and wooded land; unproductive land and even the land occupied by the farm buildings including the house of the holder.

367. However, the use of this concept is used only for settled agriculture. When shifting cultivation is defined as

> "the practice of clearing and preparing cultivation plots of land in the reservoir of natural vegetation, such as forest and grassland, growing crops on them for a number of years, and then abandoning them when the soil is exhausted",
>
> the concept of total area of the holding is limited to
>
> 1. "the area under crops during the reference period"
> 2. "the area prepared for cultivation but not sown or planted at the time of enumeration".

368. On the other hand, in the Programme for the 1970 WCA, the case of holdings composed partly of settled agricultural land and partly of shifting cultivation was considered and treated the two parties separately. For the first part, the general concept, as defined in para. 366 was to be applied while for the second part, the concept as given in para. 367.

369. The definition of the concept of "Land temporarily fallow" as given by the Programme for the 1980 WCA para. 45 allows up to 5 years of fallow in settled agriculture. In many countries reporting shifting cultivation, the period of fallow may be as low as one year and in most cases less than 5 years. As an illustration, the crop-fallow time ratio in the so-called shifting cultivation areas of Venezuela and Mexico is given in Table 13, [16,17].

370. The classification of the system of cultivation into "settled" and "shifting" could be based on different criteria all taking into consideration both the period of cropping and the period of fallow. For example, it could be based on the land-use indicator given in para.364 together with a minimum period of fallow (e.g. 3-5 years) and maybe some other quantifiable agronomic characteristics (e.g. no agricultural operation is carried out on the land during the period of fallow or abandonment).

371. If the extent of shifting cultivation is to be estimated not only a good classification of the system of cultivation, as mentioned above, is needed but also that this structural aspect of agriculture be an integral part of the programme of censuses of agricultural and that the data on crop areas, etc. be tabulated separately for settled and shifting cultivation.

Table 13. Crop-Fallow time ratio (shifting cultivation in Venezuela and Mexico[1/]

Venezuela			Mexico		
Location	Cropping period in years	Fallow period in years	Location	Cropping period in years	Fallow period in years
Merida, Zulia	1 - 2 *	1 - 2 *	Temascal	2	5
Caimital	1 - 2 *	1 - 2 *	La Capilla	4 - 5 *	2 *
Rio Jimeny	2 - 4	4 - 5	Paso Atzihuatl	1	3
Las Mesitas	2 *	2 *	Tiliapa	5 *	3 - 4 *
Las Playitas	1	3 - 4	San Martín	2	10
Agua Salada	5 *	2 - 3 *	S.A. Tenajapa	2	3 - 4
La Quebrada	8 - 12*	2 *	Tequila	1	3
Sabana Alta	1	3 - 4	La Perla	2 - 3 *	2 - 3 *
Barinitas	1	3	Tuzantla	2	4 - 5
La Plazuela	3 *	1 *	Xometla	2 - 3 *	2 - 3 *
La Pastora	3	5	Pte. de Guadalupe	1 *	1 - 2 *
Nirgua	2 - 3	5	Teotitlán	10 - 12*	2 - 3 *
La Palmita	1 - 2	1 - 5	Las Cruces	2 - 3 *	1 - 2 *
Boconó Road	4 - 5 *	2 *	Calipán	1 *	1 *
Calderas	1	5 - 7			
Riacito	3	4 - 5			
Uribal	1	4 - 5			
El Cineral	1 *	1 *			
Mucachies	2 *	1 *			

1/ Extracted from the publications [16] and [17] of the list of References

* Cases where shifting cultivation is not evident.

372. The application of the concepts of total area, crop area, fallow, etc. can be different when the shifting cultivation is practised by an individual farmer or when it is a communal or tribal undertaking. In the first case, the cultivator owns no land and is on search for new lands on which to set up some fields. These lands are nearly always taken from the forest (woods or bush) because the rights of ownership in the forest, etc. are usually ill defined or badly protected. The cleared land is cultivated on a squatter basis for one or more years and then abandoned for ever. In such a case, the total area is the cropped area and no other land use category can be considered.

373. The communal shifting cultivation system is different. The community (village, tribe, etc.) has ownership or cultivation rights over a land area, the boundaries of which are more or less well defined. The clearing of a new area to be cultivated is carried out on a communal basis. The cleared land is then subdivided amongst the farming households of the community and, in most of the cases, the cultivators follow a common system of rotation of the crops from year to year during the cropping period established by custom from time immemorial. Estimating or measuring crop areas in such a case is not a difficult undertaking especially when, during the first year, the totality of the cleared area is under a single crop (e.g. rice in the Far East, maize in Latin America) and later under a specific crop or mixture of crops. Moreover, it does seem possible to estimate the areas of the different land use categories and study their evolution in time under such a system of rotation.

374. Shifting cultivation, like other forms of primitive agriculture, based on the exclusive use of human energy, simple tools like hatchet, digging stick or hoe and only rarely the plough, and where no attempt is made by the farmers to improve or conserve the fertility of soil through the use of fertilizers or manures, leads to the rapid decrease of the soil fertility and the exhausting of its water resources and hence a decline in the crop yields and productivity of the land. In fact, in the last year before fallow, the yield is generally less than one half of the yield obtained during the first year after clearing the land. This makes it essential to measure accurately crop yields and evaluate the productivity of the land under conditions of shifting cultivation.

Mixed Cropping

375. The Programme for the 1980 World Census of Agriculture presents the problem of mixed cropping as follows:

> "Mixed crops refers to two or more different temporary or permanent crops (but not both temporary and permanent crops) grown simultaneously on the same field or plot. The number, kinds and proportions of the crops in the mixture will generally vary according to the prevailing practices in various countries or regions within the same country and to other factors, such as meteorological conditions.
> When both temporary and permanent crops are grown simultaneously in the same field, each of the crops is referred to as an associated crop. This situation should be distinguished from that of crop mixtures as defined above (i.e., combinations of temporary crops or combinations of permanent crops).
> The situation when a particular crop is planted between rows of another crop (e.g., sorghum and groundnuts between rows of cotton or groundnuts between rows of maize or sorghum) is usually referred to as interplanted crops. It may be differentiated from mixed temporary crops and from associated crops".

376. The Programme also proposes the following:

"For crop mixtures it may be practicable and desirable to estimate the area which each crop would have covered if it had been grown alone. Various methods are in common use, or may be devised, for estimating the area to be assigned to individual crops in the mixture. Such methods may be based on quantities of seed used for the crops in the

mixture, densities of plants in temporary or permanent crop mixtures as compared with the usual density in pure stands, eye estimates of the proportions of areas occupied by component crops (if distinguishable), the number of plants or trees per unit of area, etc.

377. It is generally desirable to assign the area of interplanted crops to the individual crops in proportion to the areas occupied by each crop. The aggregated yields of some mixed crops may be as large as or even larger than their yield when they are grown along (e.g. sweet potatoes and maize, maize and peas; or beans). Nevertheless, the total of area equivalents assigned to individual crops should be equal to the total area under the mixture, even when favourable inter-actions in the case of special mixtures may result in increased yields. The method to be used for assigning areas under each of the associated crops may differ among countries in view of the prevailing variations in their agricultural practices. Some difficulties will be encountered with respect to the definition of estimated area equivalents for the components of the mixture. In general, estimated net harvested areas are suggested to be reported for temporary crop components of the associated crops and estimated gross areas for permanent crop components. If the permanent crop is a compact plantation, the whole gross area may still be assigned to it. No general recommendation is made in the 1980 Programme as to the methods to be used in assigning the areas under associated crops to the individual crops concerned. Countries may use different methods for different categories of associated crops, although it is recommended that they indicate the procedures used in the allocation of such areas in their census reports".

378. The term "mixed cropping" will be used indifferently for the three cases: mixed crops, associated crops and interplanted crops especially since, for purposes of crop areas and yield statistics, there is no significant difference in the statistical treatment of the data. In some African countries, fields on which mixed cropping is practised show a large diversity of different crop combinations. For example, in the 1960 agricultural census of Gabon, the 10 principal annual crops accounted for 238 forms of crop mixtures. Moreover, the number of different crops within a single field can be as large as 10 or more. For this reason, some kind of arbitrary rule should be established permitting to ignore those minor crops which are barely represented in the field. Such a rule could be the following:

- when these rare crops are permanent ones, they could be considered and classified as scattered trees and no area attached to them;
- if the density of an annual crop is less than 10% of its normal density, this crop could be ignored.

Estimating crop areas in mixed cropping

379. In what follows, it is assumed that the areas of the fields or parcels, on which mixed cropping is practised, have already been estimated or measured and that the problem is how to estimate the area of a particular crop (i.e. separately each of the crops) in the mixture. Some simple methods have been widely practised in the past, others, more complicated, have been recommended but very rarely applied.

380. Where only a few common combinations of crops are encountered, perhaps the easiest method is to record area statistics in total for each combination separately. The method is of limited application because in practice the number of combinations is usually considerable and because no specific area is assigned to each individual crop. One variation of this method is to select what may be considered the most important, or primary crops and to classify all combinations involving that particular primary crop into the same group, thus reducing the number of groups involved (e.g. maize and other crops).

381. The principal or predominant crop is determined and the entire area of the mixed

crop field attributed to it. The criteria adopted to select the principal crop in the mixture will depend on the aims of the survey. Usually the crop occupying the greatest area will be selected when the mixture is of crops of similar botanic habit. The area occupied may be determined in such cases either by eye inspection or by a count of the relative number of plants in selected unit areas. In other cases the principal crop may be selected in terms of the value of production.

382. This method has the advantage of being easily adopted and giving a total area for all crops in pure stand and under conditions of mixed cropping which will correspond to the total national cropped area. However, when, as is often the case in practice, particular crops are more frequently the dominant members of mixtures than others, the method gives an overestimate of the actual areas of some crops and an underestimate of that of others. No information is made available on the areas which are always the minor constituents of mixtures.

383. A variation of this method is to record whether a given crop constitutes the principal constituent of a mixture or the secondary constituent. A principal millet mixture for example is one in which millet is the predominant crop. A secondary millet mixture is one in which, although millet is present, it is not the predominant crop. For each crop, figures are then shown separately for the area under pure stand, the area under principal mixtures and the area under secondary mixture. An illustration of this form of recording areas is given in Table 14 from the results of the 1960-61 agricultural sample survey of Senegal.

Table 14. Record statistics of total area to principal and secondary crops: Senegal 1960-61

Crop	Pure stand	Principal mixture	Total	Secondary mixture
	.....	Thousand hectares		.....
Groundnut	345	347	692	30
Millet	255	58	313	313
Rice	46	1	47	0
Niebe	2	0	2	88
TOTAL	648	406	1 054	431

384. In another approach, the area of a mixed crop field is attributed to every crop found irrespective of the relative importance of the various crops in the mixture. Under this method, area figures over a region or a country will over-estimate the importance of every crop and the total areas for all crops will far exceed the total cropped area. Also, when the composition of mixture is variable, comparisons from one region to another or from one period to another are difficult.

385. In some cases, particularly where the mixture consists of plants of similar botanical habit, the total area of a plot is divided by the number of crops in the mixture, and equal area is allocated to each. The method is obviously arbitrary and not suitable for situations in which some components of mixtures are consistently of greater or less importance than others.

386. Eye estimates of the proportions of a plot occupied by each crop in a mixture are sometimes attempted. The method is highly subjective and likely to produce a useful result only in the case of mixtures of similar crops at the same stage of growth or where fairly regular and systematic systems of intercropping are in use. When the mixture of crops is variable over the plot eye estimates of the areas occupied by each crop may become difficult.

387. Different approaches to the estimation of the area under the individual crop of a mixture can be evolved depending on the use to be made of the statistical data. If the data is meant to show the allocation of the physical area (land-use categories) to the different component crops of the mixture, the procedure is not the same as when the objective is to study the productivity of the system, e.g. comparing the performance of mixed cropping to that of crops cultivated under conditions of pure stand.

388. The estimation of the crop area through the two approaches yields completely different statistical data pertaining to two different concepts of area. The first denoted by "allocated area" is that fraction of the physical field area in which the particular crop is cultivated. The sum of the allocated areas of the different crops in the mixture should be equal to the total physical area of the field. The second denoted by "imputed area" is the area which would have been occupied by the crop had it been cultivated in pure stand. In general, the sum of the imputed areas is not equal to the physical area of the field. The ratio between the imputed area and the physical area can be considered as an indicator of the intensity of cultivation of the land.

389. As an illustration of these concepts, consider the following case:

A field of size 2 ha contains 4 mixed crops A, B, C and D. Let the production obtained from the field be: 200 kg, 800 kg, 600 kg. and 500 kg. of produce respectively.

Let the average yield per hectare of the crops A, B, C and D when cultivated in pure stand be: 500 kg, 1 000 kg, 750 kg. and 1 000 kg. respectively.

The imputed areas on the basis of production (i.e. the area which would have given the same production had the crop been in pure stand) are 0.40 ha, 0.80 ha, 0.80 ha and 0.50 ha with a total area of 2.50 ha.

390. This means that a field of size 2 ha with the mixed crops A, B, C and D yields the same overall production as an area of 2.50 ha of the same crops cultivated in the same proportion in pure stand. In order to obtain estimates of the allocated areas (always on the same basis of a criterion of production), the imputed areas have to be reduced using the factor 2.00/2.50 giving the respective areas: 0.32ha, 0.64ha, 0.64 ha. and 0.40 ha. respectively, the sum of which is 2.00 ha. equal to the physical area of the field.

391. Imputation of crop areas in mixed cropping can be based on different criteria. However, these criteria should depend on those characteristics of the crops which are highly correlated with either the area or production. The main characteristics which can be used for the imputation of areas are:

- the amount of seeds
- the density of the plants (mounds, hills, etc.)
- the volume of production
- the commercial value of the produce.

The choice of the proper characteristic depends on its relevancy to the objectives of the survey and also on the availability of the data.

392. The calculation of the imputed area is quite simple and depends only on the knowledge of the value of the characteristic under conditions of mixed cropping (value which is to be either estimated or measured) and on its average value when the crop is cultivated in pure stand (which could even be a theoretical standard value). The procedure is as follows:

Let

A be the physical area of the field

i a subscript denoting the order of the crop in the mixture

c_i the numerical value of the characteristic for crop i under conditions of mixed cropping

C_i the corresponding value of the same characteristic of crop i in a field of pure stand,

then, the imputed area A_i of the crop is equal to:

$$A_i = A \frac{c_i}{C_i}$$

393. The allocated area is proportional to the imputed area and the conversion factor is calculated in such a way that the sum of the allocated areas to the different crops in the mixture is equal to the physical area of the field. The conversion factor is therefore equal to

$$\frac{1}{\Sigma \frac{c_i}{C_i}} = \frac{A}{\Sigma A_i}$$

and the allocated area A_i' for crop i is given by

$$A_i' = A \frac{\frac{c_i}{C_i}}{\Sigma \frac{c_i}{C_i}} = A_i \frac{A}{\Sigma A_i}$$

394. The different characteristics to be used in the imputation or allocation of areas to different crops are not always readily available. The holder usually knows the quantity of seeds he has utilized (in some local unit of measurement) but not always the amount to be sown in case of pure stand cultivation. The average amount of seeds in case of pure stand cultivation could be collected from the farmers, theoretically determined or decided upon a posteriori. Information on crop density in mixed cropping can be obtained through the use of density plots or in counting the number of plants within the crop-cutting plot. The theoretical average density for the crop in pure stand can be derived from averages calculated for regions, districts, provinces, etc. depending on available information. The production under conditions of mixed cropping and also in pure stand can only be obtained after the crop has been harvested and the production measured. The commercial value of the produce requires a study of crop prices to supplement the information on the volume of the production.

395. When the imputation of crop areas is based on the criteria of the amount of the seeds sown or the volume of the production obtained during the totality of the time reference period (agricultural year), the case where some of the crops in the mixture are harvested before other crops are planted and thus added to the mixture (a combination of mixed and successive cropping), is automatically covered. In such a system of estimation of crop areas, the problem of successive cropping reduces to a special case of mixed cropping.

396. In the presentation and/or tabulation of the results on crop areas under conditions of mixed cropping, it would be very useful to present separately the following four types of areas for each particular crop:

(i) total area of the crop in pure stand
(ii) total area of the crop mixed with others
(iii) total imputed area of the crop
(iv) total allocated area of the crop.

This would permit different types of aggregation, namely:

(i) + (ii) is the total physical area on which the crop is cultivated
(i) + (iii) is the total area which could be used for the calculation of the crop production (multiplying it by the average yield in pure stand)
(i) + (iv) is the total land-use area of the crop.

Estimating crop yields and/or production

397. The estimation of crop yields and production under conditions of mixed cropping hardly presents any new theoretical problems. The methods presented in Chapters II and IV are still applicable although the actual labour of conducting the assessment of yields is much greater per field (or parcel) because of the presence of a number of crops.

398. When, in a system of crop reporting locality-wise, the average crop yields in pure stand are eye-estimated for each locality, the average yield of a particular crop in pure stand thus estimated can be considered to be also the yield of that crop when mixed except that in the latter case the yield does not refer to the production per unit physical crop area but to the production per unit imputed area. The total imputed area of the crop in the locality has to be estimated (or calculated) and the production of the mixed crop is obtained by multiplying the total imputed area by the estimated average pure-stand yield.

399. When the yield is objectively measured through sample crop-cutting surveys, the situation is totally different. In that case, the area to be considered is the physical crop-cutting plot area and the yield is the measured (weighed) production from that particular plot converted to refer to a physical area unit. It is to be noted that the density of the crop within the crop-cutting plot may vary randomly from zero to pure stand density or more according to its position within the field. The production is then calculated as the product of the gross physical area of the field by the yield per unit physical area. Moreover, it has to be recognized that the presence of a number of crops on the same piece of land greatly complicates the work schedule of the enumerators. The enumerators may have to go back to the fields as many times as there are crops in the mixture.

400. When yield figures of mixed crops are referred to the physical area of the field, they are likely to be subject to much more variation than in the case under pure-stand

cropping conditions. This is due to the fact that, in addition to the variation in the yield between plants, there exists a wide variation in density of plants between crop-cutting plots and also between fields. Moreover, there might also be some variation due to the interaction between the different crops in the mixture, the presence of one crop may have a beneficial or detrimental effect on another.

401. When the yield per tree or plant is estimated or measured, there is no difference in the method of estimation of the average yield or the total production whether the trees or plants are cultivated in pure stand or under mixed cropping conditions. For the estimation of the production, the number of trees or plants and not the area is the basic information needed besides the average yield per tree or plant.

Continuous planting and/or Harvesting

402. In agricultural statistics, the term "continuous" is usually used to mean that an operation is repeated at intervals of time. These repetitions could be: once a year (current statistics), 2-3 times a year (at each agricultural season) or much more often at regular or irregular intervals. In what follows, both the cases where the number of repetitions is small and large will be considered, even though, in general, the case of 2-3 repetitions does not present any particular difficulties.

403. Continuous planting during one agricultural year can take different forms:

1. successive planting of the same or a different crop on the same land (one crop is planted after another has been harvested);

2. replanting the same crop on the same land after it has been damaged (totally or partially) through natural or other causes;

3. enlarging gradually (at intervals of time) the area of land planted to one or several crops.

404. Case 1 of successive cropping does not present specific problems. The crop areas are to be estimated or measured in the usual way and the FAO recommendations for recording the results are simple. They are the following:

> "The area of successive crops is to be reported for each crop separately for each time the area is sown or planted during the agricultural year. Thus if two different crops are grown one after the other on the same field, the area of that field will appear twice in the results, once under each of the two crops concerned and sometimes more in countries having more than two cropping seasons. Similar counting of areas also occurs if the same crop is grown successively during the agricultural year. Thus the total of reported crop areas for the agricultural year may be, and usually is, larger than the total physical area."

405. It is to be noted that the imputed area, based on the amount of seeds, would have shown the same results. Also that this system of recording the results is quite useful as it permits the calculation of an indicator of land use intensity or of the extent of multiple

cropping namely the ratio between the total cropped area (temporary crops only) and the total arable land area.

406. In case 2, where the crops are damaged and the farmer has to replant or reseed the total or part of the field, it might still be useful to record, as planted or sown area, the sum of the two areas: the original area of the field and also that part of the field which has been replanted or reseeded. In such a case, the ratio between the area harvested and this total area planted can serve as a measure of the intensity of the damage.

407. In the above section on mixed cropping, the estimation or calculation of the imputed crop areas or the allocated crop areas was based on the assumption that, at one point of time, all the crops in the mixture existed and could be observed in the field and that the relevant characteristics (e.g. the density) could be estimated or measured. In general, this is not the case. The constituent crops in a mixture may have been planted at different times, have unequal growing periods and have different harvesting frequencies. For example, in a mixture of maize, cassava and plantain, the maize may be cleared in four or five months, cassava may be partially harvested from 9 to 30 months. Thus, the structure of the crop mixture varies according to the time of observation which further complicates the problem of mixed cropping.

408. Case 3 can be considered as the typical case of continuous planting as practised in a number of countries. This system of continuous planting could be illustrated as follows: a piece of arable land is inundated, then gradually the water evaporates leaving areas suitable for cultivation. The farmer, at regular or irregular intervals of time, plants one or more crops in the drying sections of the land which could consist of more or less parallel strips or at times of concentric rings. The planted crop or crops could be the same in each strip or ring or they could be different.

409. In all the cases mentioned above, the estimation of crop areas cannot be carried out in single-round surveys. The surveys should be multi-round surveys and the number of rounds should theoretically be equal to or larger than the number of different configurations of the crops in the fields. In a system of regular periodic reporting (monthly, bimonthly, quarterly) the number of rounds for the estimation or measurement of crop areas under a system of continuous cropping could be the same. However, the number of rounds should preferably be 4 or more since some of the crops may have a very short growing cycle.

410. In such a system, the estimated or measured area of a particular crop may and generally is different in each (or in some) of the different rounds. Given a time reference period (generally the agricultural year or 12 months) the problem consists in elaborating a mathematical formula which would combine the different results and produce an unbiased estimate of the crop area.

411. The following simple formula is proposed:

Let

T be the time reference period

n the number of random or systematic rounds,

i denoting the ith round (i = 1, 2, ..., n)

c the crop under consideration

A_{ci} the estimated or measured area under the crop c at the ith round (A_{ci} is equal to zero if the crop has not yet been planted or has already been harvested)

t_c the length of the average growth cycle or the average time of soil occupation of the crop c.

The unbiased estimate $\hat{A}_c$ of the area under crop c is given by

$$\hat{A}_c = \frac{\sum_{i=1}^{n} A_{ci}}{n} \times \frac{T}{t_c}$$

or the average of the estimated or measured area multiplied by the ratio between the time reference period and the average time of soil occupation.

412. In order to illustrate the use of the formula in cases of continuous cropping, some numerical examples are given hereafter.

1. Case of successive crops

The agricultural year goes from September to August. A crop which, on the average, occupies the soil during 4 months is planted successively in September and April in a field of 2 ha.

With monthly rounds its area will appear as

2, 2, 2, 2, 0, 0, 0, 2, 2, 2, 2, 0 ha

and the estimated area $\hat{A} = \frac{16}{12} \times \frac{12}{4} = 4$ ha.

With bimonthly rounds, it is still 4 ha while, with quarterly rounds, it could be equally 4.5 ha, 4.5 ha or 3 ha according to the timing of the rounds. However, the mathematical expectation of the area is once more 4 ha.

2. Case of cassava

A field of 3 ha is planted with cassava in January. The average soil occupation period is 22 months. The agricultural year goes from September to August.

With monthly rounds the area under cassava will appear

during the first year as: 0, 0, 0, 0, 3, 3, 3, 3, 3, 3, 3, 3
during the second year as: 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3
during the third year as: 3, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0

The estimated area for the first year is $\frac{24}{12} \times \frac{12}{22} = 1.09$ ha

for the second year $\frac{36}{12} \times \frac{12}{22} = 1.64$

for the third year $\frac{6}{12} \times \frac{12}{22} = 0.27$

Thus, the total area of the field: 3 ha is subdivided over the 3 years.

3. Case of gradual continuous planting

On a parcel of land, a crop which has a 5-month average period of soil occupation is planted gradually as follows:

1 ha, then 2 ha, then 3 ha, 4 ha, 0 ha and 3 ha successively, during the first 6 months of the agricultural year. The observed monthly area figures are:

1, 3, 6, 10, 10, 12, 10, 7, 3, 3, 0, 0, ha.

The estimated area on the basis of monthly rounds is 13 ha.

The estimated area on the basis of bimonthly rounds could be either 12 or 14 ha.

The estimated area on the basis of quarterly visits could equally be 14.4, 12.0 or 12.6 ha.

Finally the estimated area on the basis of a round each 4 months could equally be 14.4, 12.8, 13.6 or 11.2 ha.

In all cases the mathematical expectation of the estimated area is 13 ha which is the actually planted and harvested area during the year. Thus, the estimate of the area under the crop is unbiased, but its variance is increasing as the number of rounds is decreasing.

413. The phenomenon of continuous harvesting can be the consequence of a system of continuous planting or it can be inherent to the characteristics of the crop growth cycle which permit successive gathering of crop produce from the same standing crop. The latter situation should not be confused with successive cropping and the crop area should be reported only once unless the same crop is sown or planted more than once during the agricultural year.

414. Most perennial crops are harvested once a year. If this is done at one single occasion, harvesting is not considered to be continuous since the time reference period is generally taken to be the agricultural year. On the other hand, in the case of some specific temporary and perennial crops, not all the produce gets to maturity at the same time and the mature crop is harvested at appropriate close intervals of time (e.g. daily, weekly) during a comparatively long period (some months, e.g. oranges, vegetables, or even a whole year, e.g. lemons, tomatoes). The harvesting period can be a single one or there might be two distinct seasons (e.g. cocoa, strawberries).

415. When normally the crop is harvested at one single occasion during the agricultural year and continuous harvesting is due to the fact that the crop has been planted within the field at different times, the estimation of the yield and hence of the production cannot be carried out through the traditional objective techniques of crop-cutting random plots and weighing the produce. In the same plot would appear plants at different degrees of growth and the crop at different degrees of maturity. The same would also apply whenever the produce of the same plant matures at different times over a long period of time.

416. Objective techniques for the estimation of the yield under conditions of continuous harvesting can still be carried out if combined with some mathematical model of the growth cycle of the crop. Besides the already discussed requisites of: complete and accurate frames, selection of random fields, selection of random plots, trees or clusters of trees within the sample fields, it is necessary to carry out the following operations:

- count the number of plants within the random plot and calculate the average density of plants
- count the number of ears, cobs, fruits, etc. and calculate the average per plant
- measure the size (length, diameter, volume, weight, etc.) of the ears, cobs, fruits, etc.
- on the basis of the growth characteristics of the crop, construct a mathematical model which would relate the number and size of ears, cobs, fruits, etc. expected to mature and be harvested to their measured density and size and hence estimate the yield.

417. Whatever be the type of continuous harvesting, the simplest and most practicable method to estimate the crop yield is the subjective method. It could yield reliable results if it is based on actual observation of the planted areas; experience and previous knowledge of the crop performance; reasoning based on the crop conditions and on other relevant factors (e.g. climatic).

418. Also, the method based on the interview and declarations of the sample farmers on the amounts harvested can still be recommended. However, the method might imply frequent visits to the farmers during the harvesting period in order to investigate on each visit the volume of crop harvested during the inter-visits period. Information collected in the course of one single visit at the end of the harvesting period might be liable to large errors due to memory lapses.

Incompletely harvested crops

419. Crops, in all types of agriculture, may remain unharvested, sometimes for technical reasons such as the land being too wet to allow access, sometimes for economic reasons such as the consequent lack of incentive to harvest it. What might be regarded as a special case of this economic cause of incomplete harvesting is found when more of a reserve crop is planted than farmers find they need for subsistence use. The classic case of this is cassava in West Africa.

420. Cassava is grown in some situations as a cash crop and the ground is completely cleared when it reaches maturity, which may be from nine months after planting onwards. However, it may also be planted as a reserve crop - it is under shifting cultivation often the last crop in a cycle before the land is allowed to go back to bush. Under these conditions the usual practice is to harvest what is required, choosing the younger plants which are likely to be more palatable, and allow the rest to go to waste.

421. There are, of course, two different possible definitions of production in such circumstances. Actual production, as represented by the product harvested and used, and potential production as represented by the total crop whether harvested or not. It should be noted that, whereas the former is a reasonably clear-cut concept the latter is much less so since the weight of produce which is regarded as being available will depend on the date at which the assessment is made. As one passes from the early days of the growth of the tuber the weight available will increase until a stage is reached where parts must be regarded as inedible even under conditions of grave food shortage. After a certain point these must be written off for food purposes and the quantity available will begin, perhaps, to fall unless new growth has taken over by then.

422. The cassava problem has attracted a great deal of discussion and cannot be said to have been solved. When cassava is produced for the market, i.e.when the crop is completely harvested once for all, the estimation of yield or production does not present more difficulty than any other crop. If potential production is required, then no special difficulty other than the amount of work involved and the selection of a suitable period for harvesting the crop. In some cases, it was recommended to harvest the crop some eighteen months after the planting, however different varieties of cassava vary in the periods in which they come to maturity and the harvesting time can be brought closer to twelve months after planting. If actual production is required, the problem can only be solved in indirect ways (e.g. food consumption surveys) since it is not possible to estimate the harvested area because the farmers pick a tuber here and a tuber there amongst the growing crop as seems best to them.

423. Although in the context of developing countries cassava provides the commonest example of incomplete harvesting it may also be found in cash-crops when market conditions are too discouraging to justify further harvesting towards the end of the season. The remaining crop may be ploughed in, fed to livestock or otherwise disposed of. If this kind of incomplete harvesting is a significant feature estimates can probably be provided by reporters who are in touch with growers. Reports are usually made in terms of "proportion of the crop unharvested" or "proportion of the area unharvested" as may seem appropriate in view of harvesting custom. In practice, only a rather broad indicator of abandonment may be possible. One set of problems arises from uncertainties about definitions when growers pick over the best from their crop and leave some crop on all plants. It must be expected too that there will be a tendency to exaggerate abandonment of crop in the atmosphere of disappointment of a bad season.

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ANNEX 1-A

BELGIUM

METHODS OF COLLECTING CROP STATISTICS

1. Grain Statistics

Grain production statistics are established by the National Institute of Statistics. Collection of data concerning area readings is carried out by census agents appointed by the commune administrations. Unit yields are established by agricultural reporters working under the direction of government agronomists from the Ministry of Agriculture. Each reporter is in charge of a sector grouping 5 to 7 communes.

(a) Areas

(i) Sources of information and methods

The National Institute of Statistics makes two agricultural and garden crop censuses every year, one on 15 May and the other on 1 December. The May census covers all agricultural and garden crops, livestock, the main farm machinery and installations and manpower; that made in December covers winter sowing, standing outdoor and greenhouse garden crops, and livestock.

No forecast or current estimate is made apart from these two censuses.

A provisional estimate of results is made, based on data collected in approximately 10 percent of the communes in the country.

(1) Census listing unit: the farm.

(2) Method of obtaining results:

15 May census: individual questionnaire filled out by census agent or informant.

1 December census: census list in which the census agent enters the statements of all persons within the jurisdiction of the commune (direct interview).

(3) Exhaustive listing.

(4) Only crops standing at the date of the census are recorded. Consequently, there are no data available on the preceding or subsequent crops (the general census made every ten years contains questions on cash crops during the winter phase of the census). There is practically no actual interplanting among grain crops. Mixed crops are dealt with under two separate headings: maslin (wheat and rye); other grains and grain mixtures.

(5) The commune administrations are responsible for control of the statements collected before forwarding them to the National Institute of Statistics which, in turn, makes a probability analysis.

(6) As the ensuiry is sanctioned by Royal decree, it is compulsory; any failure or refusal to provide information is subject to prosecution, and additional surveys must be made on the spot.

(7) All persons covered by the census are obliged by law to provide information.

(ii) Crops included in census

Winter wheat; spring wheat; winter rye; spelt wheat; winter barley; spring barley; oats; maize grown for seed; maslin (mixture of wheat and rye); other grains and grain mixtures (except above mixed crop).

(iii) Definition of the term "area"

(1) Sown area.

(2) Area observed at date of census (15 May or 1 December).

(3) Generally, net area (in view of crop conditions, the distinction between net and gross area does not appear to be applicable).

(iv) Field of application

The censuses cover all farms producing for the market (regardless of size or location).

(b) Yield and production

(i) Sources of information and methods

(1) Yields are estimated by hectare of net area, by the reporter, for the whole of his sector.

There are ± 500 reporters for the whole country.

Each reporter estimates the state of crops in a classification (from 0 to 100) at the time of spearing of seed. At harvest time he makes a provisional estimate of yields, and when the crop is brought in he gives a final estimate.

Yield estimates cover the principal crops (standing on 15 May).

The national unit yield is obtained by weighing the yields supplied by each agricultural reporter by the areas recorded during the last 15 May census, the areas being grouped by sector beforehand.

(2) An estimate is made of the unit yield of the wheat-rye maslin crop.

(3) The yields published are estimated by sown area unit; this is generally the net area. However, the yield estimate covers output harvested (hence, losses in harvesting and threshing are taken into account).

(4) Production volume is obtained by multiplying the areas noted on 15 May by unit yields. No correction is made in the area and yield figures.

(5) Production estimates, based on weighted unit yields, are made simultaneously for the whole country, the provinces and the agricultural areas.

2. Fruit and vegetable statistics

The National Institute of Statistics and the Ministry of Agriculture are responsible, each within their respective fields of competence, for the establishment of fruit and vegetable statistics.

(a) Vegetables

(i) Sources of information and methods

The National Institute of Statistics takes two agricultural and market-garden crop censuses every year, one on 15 May and the other on 1 December. The May census covers all agricultural and garden crops, livestock, principal farm machinery and installations and manpower. The December census covers winter sowing, standing outdoor and-greenhouse garden crops, and livestock.

No forecasts or current estimates are made apart from these two censuses.

(1) Census list unit: the farm.

(2) Methods of obtaining results:

15 May census: Individual questionnaire filled out by census agent or informant.

1 December census: Census roll, in which the census agent enters the statements of all persons coming within the jurisdiction of the commune (direct interview).

(3) Exhaustive listing.

(4) Only crops standing at the date of the census are recorded, therefore no data are available on the preceding and subsequent crops.

(5) The commune administrations are responsible for control of the statements collected before sending them to the National Institute of Statistics which, in turn, makes a probability analysis.

(6) As the enquiry is sanctioned by Royal decree, it is compulsory; any failure or refusal to provide information is subject to prosecution and additional surveys are made on the spot.

(7) All persons included in the census are obliged by law to provide information.

(ii) Census crops

May census

(1) Outdoor commercial crops: green peas; green beans; kitchen-garden carrots; white celery; spinach; chervil (all crops are divided, on the

one hand, for the canning industry; and, on the other hand, for fresh consumption); onions (small white onions for canning, and other types); "Witloof" chicory; tomatoes; cauliflower; asparagus; cabbage lettuce; red cabbage; white cabbage; "Savoy" cabbage; turnips; shallots; green celery; celerica (turnip-root celery); salsifies (scorzonera); endives and escaroles; gherkings; radishes; rhubarb; other vegetables (not including strawberries).

(2) Commercial crops raised in greenhouses or under plastic cover; tomatoes raised in hothouses and under cold glass; cucumbers; gherkins; melons; other vegetables.

(3) Kitchen-garden crops raised exclusively for informant's home consumption: kitchen-gardens, area under greenhouses, storage facilities, frames, cloches (bell glass).

December census:

(1) Commercial outdoor crops; brussel sprouts; winter turnips; spinach; lamb's lettuce; broccoli.

(2) Commercial crops under glass or plastic cover; cabbage-lettuce; lamb's lettuce; spinach; celery; chervil.

(iii) Definition of the term "area"

(a) Sown area.

(b) Area observed at census dates (15 May or 1 December).

(c) Original net area.

(iv) Field of application

The censuses cover all farms producing for the market (regardless of size or location).

(v) Production estimate

Production estimates are made from two to four times a year, with the collaboration of an advisory commission consisting of producers, merchants, and government horticultural advisers. Market and home-consumption production of vegetables included in the May census are estimated separately.

(b) Fruit

(i) Sources of information and methods

The remarks on the heading "Vegetables", 2(i) above also apply here, except that fruit crop areas are covered in the annual May census only.

(ii) Census crops

(1) Outdoor commercial crops; tall and short standard (trunk) fruit plantations (including field orchards whose fruit harvest is intended for the market and new plantations not yet in production), divided into tall standard orchards with or without inter-cropping on the one

hand and, on the other hand, low standard orchards with or without inter-cropping. Small fruit crops; strawberries for the processing industry and for consumption, fresh; raspberries; gooseberries; red currants; mulberries.

(2) Commercial crops grown under glass or plastic cover: grapes (by varieties); peaches; strawberries; other fruits.

(3) Outdoor fruit crops for informant's home consumption.

In addition, it should be noted that at the last general agricultural census of 1970 the listing of fruit trees was made by species, varieties and age groups. Every year during the May census, data are also compiled on new short standard fruit plantations and on changes in these plantations either through uprooting or re-grafting.

(iii) Field of application

cf. under item "Vegetables" 2(iv).

(iv) Production estimates

Production estimates are established in the same way as those for vegetables, and cover the following items: apples, pears, cherries, gooseberries, strawberries and grapes.

Contrary to the case of statistics on vegetable production, those on fruit production concern only production for the market.

ANNEX 1-B

BRAZIL

METHODS OF COLLECTING CROP STATISTICS

1. Area and Yield

Statistics of area and yield have been regularly obtained through the Municipio Agent in each Municipio for some 30 years. The collection, scrutiny and tabulation of these statistics is carried out by a section in the ETEA which is located in the Ministry of Agriculture.

Every three months, on April 1, July 1, September 1 and January 1, the Municipio Agent completes two detailed questionnaires - one for temporary and the other for permanent crops, between them covering most crops.

The first part of each questionnaire deals with crops harvested during the three month period, the second part with crops in the process of cultivation.

The questionnaire on temporary crops asks for the following information for every crop listed:

area harvested during the quarter; yield per hectare; estimate of quantity produced during the quarter; average price per unit obtained by the producer; total area planted during the quarter; expected yield per hectare; state of growth of the crop; and month of sowing.

If two crops are grown mixed in one field, the area of the field will appear twice, once under each crop.

For permanent crops the following information is sought:

area harvested during the quarter; yield per hectare; yield obtained per unit of measurement; estimated production during the quarter; average price per unit obtained by the producer; number of trees or bushes new or in production; spacing; average yield per hectare; expected yield per unit of measurement (such as fruits per 100 trees, kg per tree, etc.), and condition of the crop.

The Agent is required to consult knowledgeable people in the Municipio before filling in the quarterly returns. One copy of the quarterly returns is sent to the Agricultural Department of the State Government and a second copy to the ETEA of the Ministry of Agriculture of the Federal Government. Often the statistics developed from the two copies do not tally, but no attempt has so far been made to reconcile seriously the discrepancies in these results.

It had been felt for some time that the whole process takes far too long. To speed the process a stratified probability sample of about 1 000 Municipios in the country has been selected. The Agents in charge of these Municipios are instructed to send in the return for the last quarter of the year within a period of one month, and from this sample a preliminary estimate of area and production of eighteen 18 principal crops for a calendar year is issued in the month of March of the succeeding year. The sampling errors of estimates so obtained are fairly small.

2. Forecasts

In 1962 forecasts of at least some of the important crops were provided for by a new organization, Serviço de Previsão de Safras, established in the Ministry of Agriculture which merged into the ETEA in the Ministry in 1967.

The country was divided into three major regions, the North, the North East and the Centre-South, on the basis of the Agricultural Calendar. Two forecast estimates, the first at the time of sowing and the second at the time of harvesting, are issued every year for the first two regions. For the Centre-South, three estimates are issued every year in respect of 14 crops, the first at the time of sowing, the second about a month before harvesting and the third at the time of harvesting.

A probability sample of Municipios is chosen for each selected crop, using as the frame the list of Municipios shown as producing the particular crop two years earlier, prepared by the ETEA in the manner indicated earlier. A stratified probability sample, with optimum allocation of the size to each stratum, is then prepared. A sample of about 1 000 Municipios for all the crops together is finally selected.

The forecasts of production and area are collected on the basis of a group interview with knowledgeable people at the Municipio Headquarters. The supervision of the work at the state level is done by the statistical agency of the Federal Government located at the State Headquarters, with the enumeration supervised by middle level technicians usually employed in the various related Federal or State Agencies - not by the Municipio Agent.

Very wide differences occur between figures obtained by this procedure and the corresponding figures obtained later through the Municipio Agent but no serious attempt has so far been made at reconciliation.

3. Surveys for Collection of Basic Statistics in the State of São Paulo

The State Department of Agriculture in the State of São Paulo has developed its own modern and effective system of collecting current agricultural statistics using probability sample surveys at the producer level. The State has experimented with various frames for the selection of a stratified sample, and has also been trying to utilize air photos for selecting a sample in the field. The actual collection of statistics is generally done on the basis of an interview with selected producers. Estimates of area and production of the major crops of the State are obtained through these surveys. The sample is also used for obtaining forecasts. The figures of area and production prepared by the State Department of Agriculture are not used in preparing the national totals by the ETEA of the Federal Ministry. The forecast estimates are, on the other hand, used at the federal level when issuing such estimates.

ANNEX 1-C

BULGARIA

METHODS OF COLLECTING CROP STATISTICS

1. Land Statistics

Annually, and in reference to the end of year conditions, a report is made about land utilization. The whole area of the country is divided into three categories: agricultural area, forested land and wasteland. For each a separate report is made on similar lines. The agricultural area is divided into arable and non-arable land. Arable land is the main category which includes fields, fruit and strawberry plantations, rose and mulberry orchards and meadows. Non-arable land is divided into a number of groups which cover the area of natural pastures, forests, built-up areas, mines, roads, bogs, rivers, wasteland and other. Reports about each category are made by the relevant territorial boards of the Ministry of Agriculture and Food Industry, the Ministry of Construction and the Ministry of Forestry and Wood Industry, and are summarized at their central offices dealing with land. In the reports, data are given according to the category of land tenure. For the compilation of these reports, local cadastral and large-scale maps and other sources of information are used. A general report is prepared at the Ministry of Agriculture and Food Industry for the whole country. The National Statistical Office receives statistical data about land from the Ministry of Agriculture.

2. Statistics of Sown Areas, Orchards, Vineyards and Other Crops

The National Statistical Office collects from farms, in June each year, statistical data on the size of sown areas, orchards, vineyards, nurseries, roses and mulberry orchards, and artificial pastures. In August the state and co-operative farms submit data for the late and second sowings. The data collected hy the state and co-operative farms in June and August are not considered to be final and are revised twice - when the reported preliminary data on production and average yields are compiled and, in final form, at the time of the completion of the annual data on production and yields. Sown area is entered by kinds according to their disposition: crops grown alone, crops grown with other crops and second sowings. In order to establish which part of the fields are used during a given year, a category of "spring-productive sown area" is used which includes the area of winter sowings still standing at the end of the spring sowing, the area of spring sowings and the area of perennial grasses (excluding those in cultivated pastures). In order to avoid duplicating areas of crops grown with other crops and second sowings, these are not included in the spring-productive area. There are altogether 100 field crops which are divided into four main groups: grain crops; industrial crops; vegetables, potatoes, water and must melons; and fodder crops. For state and co-operative farms only, data on sowings for 22 kinds of crops by principal varieties are compiled. The areas of orchards are entered by kinds of crops, and of vines in two groups: wine grapes and table grapes. The orchard crops, vines and other perennial crops (roses, strawberries, raspberries, mulberry, etc.) are sub-divided into newly-planted, non-fruit-bearing and fruit-bearing. Areas of mixed orchards are noted. During the survey in June, the number of isolated fruit-trees and the number of trees in mixed orchards is recorded. The number of vines in vineyards is not enumerated.

In reports of the state and co-operative farms the size of irrigated sowing areas, orchards and vineyards is compiled, in addition to the general size of the area of individual crops. Harvested crops are not recorded.

Reported data about the areas in state and co-operative farms are entered by the persons responsible on the basis of measuring every parcel and are submitted to the district office of the National Statistical Office. During the last three years, in June, areas of crops in subsidiary plots of co-operative farmers, workers and employees and in plots of farmers not in co-operatives became the object of study through sample survey methods. Before 1967 a complete enumeration was carried out (except for 1937, when sample surveys were experimented with). Before introducing sampling techniques a number of studies were made, and on the basis of these studies a 10 per cent one-stage sample design was decided upon. For all villages and for towns with a population up to 5 000 inhabitants, comprehensive household lists are made. With a random start, every tenth household in these is selected. In towns with a population of more than 5 000, enumeration districts are established, and of these, a 10 per cent random sample is chosen. Interviewers visit the households chosen in the sample and determine the size of the farm area by measurement: while for the remaining areas the data are compiled by interview. After summarizing the data, the total area is estimated by means of the raising factor 10. Estimates of sampling errors are calculated for 3 to 4 districts. The sampling errors for district estimates do not exceed 5 per cent in the case of the more important crops. The employees of communal offices take an active part in this survey.

3. Production Statistics and Average Yields of Vegetable Products

The National Statistical Office estimates the volume of vegetable production in three stages: expected production (September), preliminary data (December) and final data (in April of the following year). Production refers to realized yield and excludes losses during harvesting. State and co-operative farms submit their estimates at the beginning of September for the expected yield (for some crops at that time the volume of production is already known). The accuracy of the preliminary data, which are submitted later, is much better. In the annual reports, which are submitted at the beginning of the following year, the data are based upon the final documentation on realized production. For 25 crops communal councils make estimates for the average yield per area unit of the subsidiary plots of the population. The production in these households, for the country as a whole, and by districts, is computed by multiplying the areas by the average yields. For other crops of these households, the production is determined on the basis of the estimate of the average yield, which is made in the National Statistical Office. Average yields per area unit are determined on the sown land.

ANNEX 1-D

CANADA

METHODS OF COLLECTING CROP STATISTICS

Two methods of data collection are employed by Statistics Canada. The most widely used method is the mail-questionnaires survey because of its low cost. The second involves the use of the personal interview. Each of these methods is used to collect agricultural statistical data.

Current Agricultural Statistical Activities

Statistics Canada's responsibility for the collection of farm-based agricultural data on a regular basis during each year has been assigned almost exclusively to its Agriculture Division. The only exception is the monthly survey of the agricultural labour force. Broadly speaking, these statistical series include seasonal estimates of the production and disposition of field crops, livestock and animal products; prices received from the sale of farm products, farm income and expenditures, value of farm capital; farm wage rates; and indices of farm prices and production.

About 55 separate surveys are carried out by the Agriculture Division at varying intervals during the course of a year. Most of these surveys are conducted by mail with response being on structly voluntary basis in most cases. This method has been economical, quick and quite effective for the past 50 years. However, with the rapid structural changes taking place in agriculture and the trend to fewer and larger farm units which have taken place in recent years, it is felt that this method no longer completely meets the requirements for reliable data collection. Some experimental work has already been done with objective yield counts for fruits and potatoes, and in 1972 a nation-wide annual enumerative sample survey was introduced to our system of data collection. This latter survey, presently covering about 6 500 farms, is still in the experimental stage and will probably remain so for the next couple of years. However, it will ultimately become an integral part of the survey system and will provide, on an annual basis, data which now become available only once every five years from the Census of Agriculture. These include such things as numbers of farms, land area in agriculture, and numbers of farms classified according to size of income and product type. In addition it will also provide estimates of acreages devoted to the major crops and the numbers of the more important livestock. The size of the surveys conducted by the Agriculture Division varies considerably. For one large-scale survey conducted twice each year an attempt is made to contact each farmer in Canada by mail. This involves about 350 000 farmers with a response rate of 15-20 per cent. For most of the remaining surveys, special panels of correspondents have been developed over the years which are designed to give geographical coverage and representation by size of enterprise. Each panel varies in size, but the total number of correspondents included in all of their special panels amounts to about 25 000. Usually the response rates for these panels run about 60-70 per cent. Few of the surveys are in the form of a mail-questionnaire complete census where a reply is required from all correspondents.

The following provides an outline of the surveys presently used by the Agriculture Division in the development of its current statistical series:

1. 1 June and 1 December Surveys

These semi-annual surveys are mail-questionnaire surveys designed to contact every farmer in Canada twice each year. The response is voluntary and runs from 15 to 20 per cent of total mail out. Its prime purpose is to collect information concerning crop acreages, and livestock numbers and disposition. However, over the years other areas of interest have also been covered; these include farm woodlot production, production and disposition of milk, and selected farm operating expenses. The information from these surveys are used in conjunction with census bench-mark data to provide estimates of these items for the inter-censal years.

2. Field Crop Acreage

This is a mail-questionnaire survey of about 13 000 farmers selected so that they will be representative from the standpoint of geographic location and size of enterprise. This survey is conducted at 15 March each year to determine the acreages farmers are planning to devote to each of the crops they entered to grow during the ensuing production season.

3. Stocks of Grains on Farms

About 13 000 farmers are surveyed by mail on 31 March and 31 July of each year to determine the total quantities of the principal grains and oilseeds in storage on farms at those dates. This includes whole, chopped, rolled and crushed grains regardless of whether it is home grown or purchased and regardless of ownership. It includes all grain regardless of whether it is for feed, seed or sale.

4. Progress of Seeding

This is a mail-questionnaire survey taken at 31 May of each year. It covers not only progress of seeding but also winterkilling and spring condition of winter wheat, fall rye, tame hay and pasture, and rates of seeding for cereal crops. About 13 000 farmers are contacted during this survey.

5. Yields of Principal Field Crops

Three times per year about 13 000 farmers are contacted by mail and asked to report the yields per acre of principal field crops for their neighbourhood. These yield data are applied to the acreage information obtained by means of the 1 June survey (item 1 above) to provide estimates of crop production. The first yield survey takes place in mid-August just prior to harvest. At this time information is collected concerning the probable yield of the principal crops. In mid-September, after harvest is well advanced, a second survey is taken to obtain an estimate of average yields. Finally, after harvest has been completed, a third survey is taken to determine final yields for the current crops.

6. Yields of Crops Sown on Summerfallow and Stubble

At the end of harvest, about 6 500 farmers in the Prairie Provinces are asked to report for their own farms the yields of crops sown on each of stubble land and summerfallow. At the same time operators of country elevators in western Canada are asked to report the summerfallow and stubble land yields for their neighbourhood.

7. Mustard Seed Survey

This is a survey of those firms which purchase the mustard seed from producers. It is a mail-questionnaire survey which is taken at 15 October each year. Information is collected by type of seed for acres seeded, acres under contract, yield per seeded acre (field run) and percentage dockage.

8. Forage Crop Seed Survey

A survey of those who buy forage seeds from the producers is taken each month by mail. It is designed to collect, for both pedigreed and commercial forage seeds, information about the quantities purchased from farmers and primary cleaners, quantities imported and exported, and the amounts in inventory at the end of the month.

9. Survey of Grain Millers

A mail-questionnaire survey is taken of Canadian grain millers each month to determine the quantities of grains milled, the various products produced and quantities of each on hand at the end of the month.

10. Mushroom Growers

This survey is an annual survey of all commercial producers of mushrooms, taken at the close of each calendar year. It is a mail-questionnaire survey designed to collect information concerning productions and sales, value of investment in the industry, number of employees, and wage rates.

11. Survey of Greenhouse Industry

A mail-questionnaire survey of all greenhouse operators is taken at the close of each calendar year. It obtains information about the area under glass or plastic, total investment, the number of years the enterprise has been operating, number of employees, production and sales of flowers, production and value of vegetables.

12. Survey of Intended Acreages of Vegetables

This is a mail-questionnaire survey of all vegetable processors in Canada. It is designed to provide an early indication of the acreage of specified processing crops which processors intend to contract for the current growing season. It is a seasonal survey taken prior to the planting season.

13. Survey of Contracts for Vegetables for Processing

All vegetable processors in Canada are surveyed by mail after the contracting season to determine the acreages or quantities of specified processing vegetables which they have under contract with farmers. In addition, they are asked to report any vegetable crops they are growing on land owned or rented.

14. Survey of Preliminary Vegetable Acreage

This is a mail-questionnaire survey of all known commercial vegetable growers to obtain information which will permit the preparation of a preliminary report on acreages sown to vegetables.

15. Survey of the Harvested Acreage of Vegetables

At the end of the growing season all vegetable processing firms are canvassed by mail to determine the total acreages harvested, average yields and values of selected vegetables grown under contract. They are asked to report also the same information for vegetable crops grown on land they own or rent.

16. Survey of Fall Vegetable Production

A mail-questionnaire is sent to all known commercial vegetable growers requesting information about acres harvested, total production and average sales prices for a selected list of vegetables.

17. Yields of Selected Fruits

Each year objective yield counts for selected fruits are made by means of a probability sample survey in the Niagara district of Ontario. Sour cherries are surveyed the last week in June, peaches the last week in July, and grapes the last week in August.

ANNEX 1-E

EGYPT

METHODS OF COLLECTING CROP STATISTICS

1. Area

There are two methods of estimating area under crops:

(a) An subjective method of enquiry from the farmers carried out for all crops on a complete enumeration basis by the agricultural staff with the help of village administrative people.

(b) An objective method of direct measurement in the field which is confined to some of the principal crops and is based on the use of cadastral survey maps of scale $\frac{1}{2500}$. By spot inspection measurement is made of the crop along the sides of the survey parcels and delineated on the maps with the help of a scaling ruler; the boundaries of the crop are thus identified and coded on the maps and the area is calculated by planimeter. This work is carried out on a 100% basis for cotton, rice, wheat and sugar cane. In the case of cotton, wheat and rice a 50% sample has been used since 1967 and a ratio estimate applied using data of the latest complete enumeration.

Aerial photography was applied in 1966 on a nation-wide scale to eliminate errors of coverage and measurement in the field, but errors due to the planimeter remained and there were difficulties related to the identification of crops in the photos and to errors of flight. The project was discontinued after 1967.

2. Yield

There are two methods of estimating crop yields:

(a) a subjective method by enquiry from the farmers and eye estimates by the agricultural field staff used for all crops, and

(b) an objective method, of crop-cutting for 8 principal crops (cotton, paddy, wheat, maize, onions, groundnuts, lentils, potatoes).

Under the subjective method, the agricultural field staff select by judgement 2-3 villages which they consider representative of the district and information is then collected by enquiry from the farmers and by eye estimate. The weighted average yield for the province is then obtained using the total nation-wide estimates.

For yield estimation the sampling design was a stratified multi-stage one, in which the districts and sub-districts (2-3 agricultural units within each district) form the strata. Within each stratum, the cultivated land falling in each village was divided into clusters of 200 feddans each (range 150-250 feddans) by combining neighbouring "hodes" (identifiable survey parcels). On the same basis large hodes were divided into smaller units; these constituted the primary sampling units. The allocation of clusters among the different strata was done in proportion to the area under the crop. Within each selected cluster a

a list of crop growers was prepared and two parcels selected at random. Within each selected parcel, a field growing the crop was selected out of all the fields growing this crop. The size of the plot was 7 x 12 metres (1/50 feddan) for crops grown in rows like cotton and maize, 7 x 6 metres (1/100 feddan) for paddy, wheat and lentils, and half that size (3.5 x 6 m) for onions, potatoes and groundnuts.

The number of primary sampling units (p.s.u.'s) and of plots within units was determined for each crop on the basis of pilot investigations and the analysis of components of variation between units and within units. With 2 plots per p.s.u., 305 p.s.u.'s would be needed to reduce the standard error to 2 per cent for cotton but only 84 for wheat for a S.E. of 5%, 41 and 14 p.s.u.'s would be needed for a S.E. of 5%. For cotton and wheat under operational conditions nation-wide yield estimates for the main crops have standard errors of under 1%.

Correction factors were applied to the gross area estimates to obtain the net area for use in multiplication to estimate production. The correction factor was obtained on the basis of a sub-sample of clusters included in the original sample and on using actual measurement of the length and breadth of canals, drains, ditches, etc.

In the case of cereals driage tests were applied on samples of the grains to estimate the amount of moisture lost up to the time of marketing or consumption of the crop. Double sampling techniques were also applied utilizing the ratio of grains to grains plus straw to reduce the work involved in processing the crop after harvesting to only a second phase sub-sample of the original sample of plots to increase efficiency.

ANNEX 1-F

NIGERIA

METHODS OF COLLECTING CROP STATISTICS

1. Area and Yield

The sample surveys concerned are multi-purpose in character using a two-stage stratified design to collect the following statistics: Acreage planted to different farm crops, both sole or mixture; acreage planted to economic tree crops; production of farm crops, sole and mixture, and production of tree crops; number of each kind of domestic livestock and poultry, their vital statistics, purchases and sales; household consumption of food and other items, both purchased and raised by the household; composition and occupation of household members including part-time work; price paid by farmers (derived from reported purchases in consumption surveys and reported amount paid together with expenditure for various services, e.g. hair cutting, tailors' charges, travel, etc.); prices received by farmers and prices in rural areas; number of farmers, classified by type of farming and area farmed; timing of farm operations (Crop Calendar); labour used in agriculture; and information on the use of fertilizers, insecticide, irrigations, agricultural equipment, types of transportation used for conveying produce and tenurial system of land.

The period of collection is one agricultural year beginning from April - there are two crop seasons in parts of Nigeria. Up to the 1970/71 survey a team of two members lived approximately a year in a selected village unit collecting information. With the idea of doubling the number of survey units to increase the precision of the survey, the team was reduced to one from 1970. This member had also to remain in the selected village unit for one agricultural year.

The survey included 204 village units throughout the Federation and 30 farmers' households were studied in each village unit in 1965/66 (the year before the civil war in Nigeria), a total of 6 120 households.

Estimates of production were based on the crops harvested during the year of the survey. Crops like cassava, cocoyam, etc., which may remain in the ground for more than a crop year without being harvested, were only covered for information on acreage planted if they were not harvested in the year of the survey.

The detailed list of administrative areas, with their population figures as obtained in the 1963 population census, was used as a sampling frame from which the primary sampling units were selected. Towns in the census list of each Region, usually places with over 20 thousand population, were excluded. At the second stage of sample selection, a list of households (distinguishing farming and non-farming households) compiled at the time of the survey was used as a frame.

To increase the efficiency of the survey each province was stratified into homogenous agricultural areas. Districts and parts of districts in which similar agricultural patterns existed were grouped into strata. The grouping of districts and sub-districts into strata was based on the advice of the Regional Ministries of Agriculture.

Each stratum was planned so as to have a population larger than twice the sampling interval for that Region to ensure that at least two primary units were selected from each.

The number of primary units allocated to each stratum of a Region might vary from one stratum to another, but in all cases it was approximately equal to the proportion of the population in that stratum to the total population in that Region.

The size of the primary sampling unit was fixed at between 1 500 and 3 000 population.

The primary units were selected with probability proportional to the size of population using a systematic random sampling method. If a selected village was above 3 000 population, enumeration districts were grouped to give units of about 1 500 population, one of which was selected at random. If the village selected was under 1 500 population, villages were grouped using precautions against bias.

In selecting the second-stage units (farmer's households) a Master Sample of 50 households was first selected at random from each village unit. This was classified into farming households and non-farming households. The first 30 households were selected from this Master Sample in the final sample for the farm survey. From this Master Sample, whether extended or not, a determined number of households was selected for the multi-purpose rural surveys.

Programme of Field Operations. When the enumerator got to the selected unit of study (village), he undertook the following main operations:

(a) Preparation of a rough map of the unit of study.

(b) Complete enumeration of households in the unit: The form used contains full identification.

Selection of Master Sample: From the total list of households listed in the study unit above, 50 households are selected randomly. These 50 households were called Master Samples and from these 15 farming households were selected.

The 50 households selected as the Master Sample were then subjected to detailed enquiry covering the name of the members of the household, their sex, age and occupation, and the number of farm plots being operated by the household.

For the farm survey the first 30 farming households were selected. Arrangements were made by the enumerator with the sample household to visit and measure all farm plots operated by members of the household. All farm plots within reasonable distance from the unit of study were studied (say within a 15 miles radius of the main village in the case of a group of villages or enumeration areas).

If a farming household selected possessed two or more parcels or plots of farm carrying different crops in mixture or sole, each of the plots was surveyed separately and their areas determined using usually a closed traverse method with measurements by chain or tape and compass, but where more appropriate by triangulation. The computations to assess the area of the plots were carried out in the office. Traverse data were plotted and the area measured by gridding and planimeter.

For yield estimation a yield plot of 1/40 of an acre was laid at random within the selected farm plot. Yield plots were laid in every farm plot embraced by the survey and pegged for demarcation during harvest. If a farm plot with farm crops had a perimeter of less than 240 ft (or 80 paces), the whole plot was regarded as a yield plot and harvested entirely, but in the case of plots with more than a 240 ft perimeter a yield point was randomly determined within the farm plot.

A peg was put in at this point and, up to 1965-66, with a radius of 18' 7 1/2" a circular yield plot of 1/40 of an acre was laid. For tree crops, 10 trees, whether bearing or not, were selected nearest to the peg to constitute the sample plot.

After 1965/66 the circular plot was discarded in favour of a rectangular yield plot, partly because of the crop damage in cutting the circular plots.

Farmers were requested not to remove the pegs and to inform the enumerator when they were ready to harvest. At the time of harvest, the enumerator weighed all crops harvested from the pegged 1/40 of an acre yield plot. Several weighings may be performed by the enumerator according to the nature of the crop to determine dry weight, grain weight, etc. Several harvestings may also take place for crops like cotton, pepper, plantain, cocoa and oranges, where harvesting customarily extends over a period of the whole summer, and these were all added together as the yield from 1/40 of an acre for the farm crops, and 10 trees for tree crops.

The summation of all the stratum production and the acreage of different crops multiplied by the expansion factor for the stratum gave the global production and acreage for each stratum in the Region or State of the Federation. By summing the production and acreage over all the strata in the country, the total production and acreage of different crops was obtained.

The Agricultural Analysis section kept and processed manually with desk calculating machines all field data. Some part of the section was engaged in preparation of codes for punching on cards. These source documents were finally sent to the Computer Centre of the Federal Office of Statistics where programming for the Farm Survey had already been worked out.

ANNEX 1-G

YUGOSLAVIA

METHODS OF COLLECTING CROP STATISTICS

The agricultural activity is organized in two sectors, the socialist and the private. The total number of agricultural holdings in the private sector amounts to about 2 600 thousand and about 2 thousand in the socialist sector. The arable area operated by the two sectors is 8 720 thousand hectares and 1 468 thousand hectares, respectively.

The collection of current agricultural statistics is different in the two sectors. The picture presented here is arranged by fields which are homogeneous with respect to method.

Area and yield statistics

Data falling under this title are collected each year for the whole country for the follwoing:

(i) area planted in the fall;

(ii) area at the end of planting campaign and the expected yield of early crops;

(iii) expected yield of early crops;

(iv) actual yield of early crops and fruits and expected yield of late crops, fruits and grapes;

(v) actual yield of late crops, fruits or grapes.

For the collection of data in the annual surveys a special network of "crop reporting agents" is created totalling 3 300 in the country as a whole. They report on the features included in each survey for the areas under their jurisdiction, using eye estimates.

Every agent has his reporting area based on the results of the cadastral survey. To facilitate the utilization of records the cadastral service has divided the whole country into small area units called "cadastral communes". The territory of each administrative commune is composed of several cadastral communes. The borders of the administrative communes change frequently but the borders of the cadastral communes are fixed and shown on maps. Each cadastral commune normally includes a village or a hamlet. The total territory of each cadastral commune is known from the measurement of the whole territory. In addition, the breakdown of the territory of each cadastral commune by the cadastral land utilization categories is also known.

The reporting areas are obtained by using one or more adjacent cadastral communes. In flat areas which are important from the point of agricultural production, the reporting areas often reduces to the area of a single cadastral commune. In mountains where only a small percentage of the total territory can be cultivated, several cadastral communes make up a single reporting area.

A separate agent is appointed for each reporting area. The following criteria were used in choosing agents: he is a permanent resident in his reporting area; has sufficient

general education; is preferably an agriculturist himself. The agents make a contract with the statistical service for their work and become members of the permanent crop reporting service.

In order to be able to work satisfactorily, the agents are obliged to utilize in their work the following facilities:

(i) cadastral data as to the total size of the reporting area and its breakdown by the land utilization categories;

(ii) statistical data on areas and yields for the same reporting area for the previous year;

(iii) the results of the last census of agriculture;

(iv) contacts with agricultural experts in the area;

(v) contacts with agricultural producers;

(vi) reports available on areas and yields collected by other organizations;

(vii) personal observations.

Special instructions are prepared for the reporting agents about their duties in the above-mentioned surveys. In addition to methods of obtaining data, these instructions also deal with concepts, definitions, time-table, etc.

In all the area and yield surveys data are available by reporting areas and all other larger units, such as communes, republics, and the country as a whole.

As to the characteristics included in the above surveys, the survey listed under (i) refers to wheat (high-yielding and other types separately), winter barley, oats, other cereals, four varieties of industrial crops, vegetables and six types of fodder crops.

Data are available within a week for all the units in the country, no matter what their rank on the hierarchy of units. The survey covers a comprehensive list of crops and land use items.

The programme of this survey keeps changing with a view to finding the specification of characteristics that would be considered by users as the most essential. The variations from one year to another are sometimes very considerable.

The expected yield survey listed above relates to the second estimates of the yield of early crops. It covers wheat (high yielding and others), barley, oats, rye and potatoes. Among fruit the items included are: applies, pears, plums, peaches and nuts.

Actual yield surveys cover a comprehensive list of field, vegetable and fruit crops.

The instructions prepared for the agents describe first the organization of the service. Then they set out basic concepts and definitions arising in these surveys and go into a specification of procedures that the agents are expected to follow in order to get data requested in the survey concerned.

The system described above does not relate to the socialist agricultural sector. The programme of reporting from the agricultural co-operatives is much broader. They are covered by the same basic surveys as the private sector of agriculture but they have the following supplementary programme every year:

(i) area and yield statistics on areas operated jointly by the co-operatives and the private individual holdings;

(ii) services provided by the co-operatives to the private sector;

(iii) supply of material (seeds, fertilizers, insecticides, etc.) by co-operatives to private holdings;

(iv) orchards and vineyards operated in co-operation with the private sector;

(v) land rented from private holdings.

The surveys are made by mailed questionnaire.

ANNEX 2-A

COLOMBIA

SURVEY OF AGRICULTURE

The purpuse of this survey is to obtain information on the area under cultivation, yield, stock of cattle and livestock production. In planning the survey, it was considered also that it should be possible to utilize the same design for special surveys, e.g. coffee, sugar cane, rice, other crops, and social and economic studies of the rural sector of the country.

The survey covers 16 departments of the country in which the agricultural census of 1960 was carried out. Due to special circumstances, the census operation included neither the department of Choco nor the various national territories. Despite this omission, more than 99 per cent of the agricultural holdings are located in the 16 departments covered by the census.

Information is collected on (a) areas sown with annual crops, (b) areas sown and yield in the first growing season of the year, (c) areas sown and production of permanent crops, (d) number of head of cattle, (e) number of fowl, and (f) livestock production.

Producers have become accustomed to providing the information requested. Although the majority of replies are voluntary, the Departamento Administrativo Nacional de Estadística has the legal tools under which every Colombian or foreign resident in the national territory is obliged to supply statistical data. This law has been applied only in rare cases.

The population of the survey is approximately 32 650 holdings. Of these 12 973 are specialized holdings. The specialized holdings are defined with respect to (a) surface under cultivation, (b) surface sown with coffee, (c) number of head of cattle or other livestock. The most important specialized holdings are completely enumerated. There are about 7 106 holdings in this category. The remainder of the specialized holdings are distributed over three strata: one with respect to surface under cultivation, one with respect to the number of head of cattle, and one with respect to surface cultivated with coffee. A 20 per cent systematic sample is selected from each stratum.

Cluster sampling is applied to the non-specialized holdings. The total number of holdings in each political-administrative department is calculated. To establish the number of strata in each department the total is divided by 2 400. From each stratum a number of consecutive censal sectors are chosen. These are further divided into clusters of about 20 holdings each One or two clusters are selected from each censal sector chosen.

In the 1968 round of the survey non-response amounted to 1.1 per cent of all holdings included in the sample. Of these, 0.6 per cent were cases in which the agricultural holdings were inaccessible. Adjustment for non-response is made by assuming the same distribution of characteristics for non-respondents as for respondents.

The results are published at the departmental and national levels. These appear six months after the completion of the field work.

ANNEX 2-B

FRANCE

1. SURVEY OF LAND UTILIZATION

2. CEREAL SURVEY

1. The purpose of the annual survey of land utilization is to op-date the "land distribution" section of the French annual agricultural statistics. This survey also serves as the basis for certain crop surveys.

All departmental territory is covered in this survey. This includes agricultural as well as non-agricultural territory, forests, and industrial areas. In 1969 all French departments carried out this survey, thereby providing complete results for France. The different categories of territory have been stratified into a number of strata, those being: (a) forests, (b) non-agriculture and non-forestry, and (c) agricultural. Those territories falling into class (c) have been further subdivided into eight categories: (i) cereals, viz. wheat, barley, corn and oats; (ii) plants free-of-weeds, viz. industrial beetroots and potatoes; (iii) other arable lands, viz. temporary meadows, intensive vegetable cultivations, and annually foraged fallow land; (iv) meadow land; (v) orchards; (vi) vineyards; (vii) permanent specialized cultivations and market gardens; and (viii) waste land and fallow land.

In the conduct of this survey the technique of aerial photography is used. Aerial photographs have been taken since 1956. An equal probability sample of 100 photographs geographically distributed over each French department is taken. On each sample photograph, a sketch of 72 points is drawn. These points are distributed in 12 lines of 6 equidistant points each; the distances between the points represent real distances on the ground of 300 metres. This technique yields a sample of 7 200 equiprobable points geographically distributed in bunches in 72. The total of 100 photographs per department yields a sampling fraction which varies between 10 and 20 per cent, depending on the surface of the department.

A surveyor, provided with a photographic enlargement of the field, goes to the precise place determined by a point found at the intersection of the two branches of a cross drawn on each photographic enlargement. The distribution of the 7 200 points gives a reflection of the departmental distribution of the territory, by crop and general category, e.g. cereals.

This survey is directly done on the field by the surveyors without interviewing the landlords or workers. In flat country a well trained surveyor can visit 72 points of an aerial photograph in his day's work. One department can be covered in an average of 100 days' work performed by between 5 and 10 surveyors.

This is an annual survey. It has been repeated point by point since 1965 for certain departments, thus allowing the survey to not only provide information on the current distribution of the land, but also on the development of the territory over time. This survey is carried out during the months of June and July, on a date which falls between the sowing of the seed and harvesting.

Two causes of error can arise in this survey: (a) error in noting the type of cultivation, and (b) error in location of points by the surveyor. These two types of error are revealed by re-examining a certain number of points visited by a surveyor (generally one out of 12 per photograph). The first type of error can be minimized by giving precise instructions. The second type takes on two forms: (a) systematic - and the surveyor is replaced; and (b) accidental - due particularly to changes in land use.

A calculation of error shows that inter-photo variance is much more important than intra-photo variance. To compensate for this, the photographed areas have been stratified, such that where greater variance exists the number of photographs has been doubled or quadrupled without increasing the number of points surveyed.

2. The purposes of the cereals survey are (a) to measure wheat, barley and maize production from area and yield data, and (b) to ascertain the degree to which cultivation techniques are applied and analyse them in the light of yields obtained.

Yields are estimated from samples collected from sample plots of known areas selected at random. The selection of the sample is made in several stages. Two methods may be considered, depending upon whether (a) the sampling frame used is the list of agricultural holdings, or (b) the series of data which are periodically collected for the "land survey" (see above).

Where the list of agricultural holdings is used, the "selection of holdings" technique, sampling is done in four stages. These stages consist of the selection of (a) communes, (b) holdings, (c) fields, and finally (d) sample plots.

During the first phase of the survey, farmers interviewed completed a questionnaire on the number of fields sown with common wheat, barley and/or maize. A number of questions concerning the distribution of the holding's land, storage and own consumption are also asked during the interview. On the second occasion fields are chosen by lot. For each field drawn by lot, a second-phase questionnaire is completed. This contains questions regarding the cultivation techniques used.

Finally, a third visit is necessary to take sample ears of wheat or barley from plots of approximately one square metre and samples of ears of maize from two rows five metres in length. The interviewers are told in advance from where the samples are to be taken. The ears are threshed, the grain from each sample weighed and a humidity analysis performed to give the yield 15 per cent humidity.

Where the "land use survey" is used, a random selection is made from a predetermine number of points from the population of "wheat", "barley", and "maize" points established during that survey. Sample selection is done in four stages: (a) photographs, (b) points from different categories of territory, (c) selection of wheat, barley and maize points, and (d) plots. Each of the points represents a field. The owner of the field is contacted to complete a second-phase questionnaire.

The average net biological yield per department is obtained by calculating the arithmetic mean of the yields obtained from all the sample plots in the department. Two types of adjustment factors are then applied to this yield in order to derive the true average yield per farmer or average economic yield. These adjustment factors are: (a) the average percentage area of unsown field for the entire department (these areas are estimated during

the second phase by the interviewers themselves), and (b) the percentage losses in situ and in transport.

Areas are estimated by extrapolating, at the departmental level, information obtained from: (a) the farmers involved in the first phase, where the "selection of holdings" method is used, and (b) interviewers' observations, where the "land use survey" is used in the first phase.

In the 1968 and 1969 surveys, first-phase selection was accomplished by using the set of holdings surveyed in the 1967 sample survey on the structure of agricultural holdings in the countries of the European Economic Community as the sampling frame.

In each department the holdings forming the sampling frame were divided into three strata according to the area under cereal cultivation. The first-phase sample was allocated to the strata in numbers proportional to the sum of the areas under cereal cultivation (approximately the Neyman allocation). The sample was drawn by systematic selection from a list of holdings classified by commune, and within the communes by areas under cereals in descending order. Two replacement holdings were selected for each holding.

After selection the sample was checked by reference to the criterion of area under cereal cultivation. This operation made it possible to ascertain that the average structure of the samples was, in general, identical with that of their populations from which they were drawn.

In each sample holding, the list of wheat, barley or maize fields constituted the sampling frame for selecting the fields. Fields were listed under separate headings by crop, and further stratified by type, viz. autumn or spring cereal, in the cases of wheat and barley. Selections were made with probability proportional to size first from the list of autumn cereals, and then spring cereals.

The survey was first conducted on an experimental basis in 1962 in a number of pilot departments and has been repeated each year in the departments which are the largest producers. Its scope is gradually being extended each year and the depa-rtments surveyed in 1969 account for approximately 58 per cent, 66 per cent, and 36 per cent, respectively, of all areas under wheat, barley and maize. It is planned to survey wheat and barley production for the whole of France after the 1970 general agricultural census.

The holdings are selected manually, during April, by the regional or departmental agricultural statistics authorities, from the commune survey's registers of holdings. The first-phase questionnaires are completed during April and May by the corps of interviewers from each departmental statistical service.

Preliminary processing is carried out manually during the summer to enable the results at the departmental level to be published promptly. More comprehensive machine processing is undertaken after the questionnaires have been checked at the central office for data on the structure of cereal producing holdings.

A second visit by the interviewers takes place in June or July, depending on the region. After the harvest, each sample of ears of grain is treated in one of the regional threshing centres; the grains are then weighed and their humidity is measured in departmental or regional laboratories especially equipped for the survey.

The second-phase questionnaires are processed by computer in December and January. Some 30 tables showing the distribution of areas under wheat, barley or maize, and the variation in yields in relation to various structural and technical criteria are prepared.

After editing, the main results are published in supplements to the "Série Etudes" of statistical studies.

ANNEX 2-C

INDIA

CROP ESTIMATION SURVEYS IN THE STATES

The object of these surveys is to estimate the average yield of principal food and non-food crops for each state and for important administrative divisions and districts (in each state) on an objective basis. All major crops, such as rice, jowar, bajra, maize, wheat, barley, gram, cotton, jute, groundnut, sugarcane, tobacco, etc. are covered, but the coverage is different in different states. The decision regarding a particular crop's inclusion in the survey at the state level is made on the basis of its contribution to the all-India acreage and production and the importance given to the crop by the state itself. All states and union territories are covered by this survey. Responsibility for organizing these surveys lies with the state governments concerned.

Data are collected by direct physical observation of the selected fields and by conducting crop-cutting experiments in the prescribed manner. The field staff for this work are drawn from the departments of agriculture and revenue in the state governments. A programme of training is usually arranged for such staff before each crop season. Besides explaining the purpose of this survey, concepts and procedures, a practical demonstration is given on the field. The field work of this survey constitutes a part of the regular functions of the revenue and agricultural staff in the states.

A stratified three-stage sampling design has been adopted for this survey with villages, fields and plots as the first, second and third stage units respectively. The first two of these have well defined permanent boundaries and there has been no difficulty in identifying the randomly selected unit at the field stage. The third-stage unit, namely the plot, is the only one which has to be located within the selected field by a random process during the survey. An administrative division (tehsil) within the district is taken as the stratum. A sample of villages - ranging from two to eight in number - is chosen for each crop from the list of villages of the stratum. In each of the selected villages two plots growing the crop in question are selected at random. An experimental plot of rectangular shape, usually 33 feet x 16 1/2 feet (but varying from crop to crop and from state to state) is chosen at random in each selected field. The crop from this plot is harvested on the usual harvesting day with the help and co-operation of the cultivator of the selected field. The average number of experiments for a district which is considered important for the crop in question is of the order of 100.

Data are collected during each of the harvesting seasons of the agricultural year ending June. There are two major seasons in the country, namely, the Kharif and rabi seasons. In some states, crops are grown in three different seasons.

The entire work of this survey including the design, data collection and processing, is the responsibility of the state government concerned. The field staff are the permanent members of the revenue and agriculture departments. Their work is supervised by their departmental supervisory staff. Cost estimates are not, therefore, usually compiled. There is, however, a separate agricultural statistics division in the Directorate of National Sample Survey, Government of India, which exercises an overall co-ordinating type of control over these surveys. Also, it carries out an independent supervisory check on the field work. About 200 persons are engaged in this co-ordination work at the all-India level.

The average yield per unit area is calculated from the data of all experimental plots at the stratum, district and state levels. In the case of crops sown in mixture, the yield rates are adjusted by the proportion of the area under the crop in the field, to obtain an estimate of the yield per unit of net area. This proportion for the field is obtained as an eye estimate. A dehumidification factor is also applied at the district level to obtain the dry yield rate for the crop. The production of crop in each stratum is estimated as a product of the net yield rate obtained in this manner and the net area under the crop. The net area under the crop is equivalent to the area exclusively under the crop grown plus a proportionate are of the crop grown in mixture. The estimates of production are also adjusted to account for the area occupied by bunds (small strips of land not growing any crop, separating two crop-growing fields).

ANNEX 2-D

SAUDI ARABIA

PILOT STUDY OF CROP-CUTTING OF DATES

The purpose of this survey was to develop a suitable sampling design and field procedure for organizing regular nation-wide crop-cutting surveys, to compare the reliability of estimates of yield rates between the subjective interview method and the objective method of crop-cutting, and to train related staff in the technique of crop-cutting surveys.

Four districts of the Central Province of Saudi Arabia were covered. The results of the agricultural survey of the Central Province in 1963 were used as the frame.

Districts of the province were considered as strata. Date-bearing trees were almost equally distributed among these districts. A three-stage sampling design was used. At the first stage villages were selected from which a 20 per cent sample of holdings was selected systematically. Finally a sample of date-bearing trees was selected.

At the first stage of enumeration, all managers of date holdings in the sample villages were interviewed using special forms to record information pertaining to the number of date-bearing trees in the current harvest period, non-bearing trees, and the area under date palms. In addition, information on the major varieties and period of harvest was obtained through interviews.

At the second stage, the field staff selected systematically a 20 per cent sample of hodlings for measurement of area and the count of date-bearing and non-bearing trees.

The enumeration of holdings in sample villages started on 18 April 1967 and was completed on 2 June 1967.

Two agricultural engineers and two technical assistants were appointed as supervisors. In addition, there was a team of enumerators drawn from local statistical offices in each district. The supervisors were thoroughly briefed and trained in crop-cutting techniques. Each supervisor kept detailed records of field problems and time needed for different operations. The enumerators were in turn trained by supervisors.

The division of agricultural statistics and economics, Ministry of Agriculture and Water, was responsible for the survey.

ANNEX 2-E

SUDAN

PILOT STUDIES FOR THE CROP ESTIMATION SURVEY

A series of pilot studies of the crop estimation survey on dura (sorghum) and wheat were carried out by the Department of Statistics beginning with a study on dura in 1965/66 in one council of the Blue Nile province. The studies on dura covered one council in 1965/66, seven councils in 1966/67, parts of three councils in 1967/68 and 22 councils important in the country for this crop in 1968/69. The studies on wheat were confined to pump irrigation schemes of the Northern province with full coverage of all five councils in 1965/66 and 1967/68 and restricted coverage of two most important councils for this crop in 1966/67. The crop-cutting survey on dura in 1967/68 was a part of the bench-mark survey carried out in the tract to be covered by the first phase of the Rahad Irrigation Project.

The sampling design of the studies on dura and wheat was multi-stage stratified. In the case of dura, each council covered by the survey was generally treated as a stratum. However, wherever possible a council itself was stratified into two or three strata on the basis of the crop pattern. Within each stratum a two-stage sampling design was used for the area survey with sheikships as primary sampling unit and agricultural holdings within selected sheikships as the units of sampling at the second stage. For crop-cutting experiments the sampling was extended to two more stages. Fields growing dura within each selected holding constituted the unit at the third stage and a rectangular plot measuring 7 by 6 metres was the sampling unit at the ultimate stage.

In the case of surveys on wheat, area under wheat was collected on a complete enumeration basis. For crop-cutting experiments, a two-way stratification, first councils and within each council the size of pump schemes in terms of gross area commanded was adopted. Within each stratum a three-stage sampling design was used with a pump scheme as the first-stage sampling unit, a wheat-growing field within a selected scheme as the second-stage sampling unit, and a rectangular plot measuring 7 by 6 metres for crop-cutting experiments as the ultimate sampling unit.

The selection of sampling units at each stage in the survey on both the crops was one at random. A crop-cutting experiment consisted of marking carefully a plot of the size indicated above in the selected field and harvesting, threshing, winnowing, drying and weighing the produce within it.

The field work of each survey was entrusted to enumerators under supervision at the rate of one supervisor per six enumerators and inspectors. The entire field staff was, at the beginning of each survey, adequately trained in the conduct of field work with numerous practical exercises. The field work was generally carried out by enumerators in batches, a batch usually consisting of two enumerators. One batch of enumerators was normally assigned 18 crop-cutting experiments in six sheikhships or pump schemes at the rate of three experiments per sheikhship or scheme and 18 sheikhships for the area survey. In the total absence of transport facilities in the rural part of the country, the department provided the field staff with motor vehicles generally at the rate of one vehicle per council.

The number of experiments conducted on dura was 212 in 1965/66, 336 in 1966/67, and 903 in 1968/69; and that on wheat was 217 in 1965/66, 151 in 1966/67, and 239 in 1967/68. Reports were made on pilot studies on wheat in 1965/66 and 1966/67 and on dura in 1965/66 and 1966/67.

ANNEX 2-F

UNITED STATES OF AMERICA

JUNE SURVEY OF CROP ACREAGES

The Economic Statistics and Cooperative Services of the United States Department of Agriculture each June conducts a survey of acreage planted to various crops and numbers of livestock. This is one of the major surveys in the department's current agricultural statistics programme. Over the past decade, improvements have been introduced as a result of research studies. Although the major emphasis is on planted acreages the survey also obtains information on number of farms, livestock, poultry and farm labour.

The June survey population is all farms and land in the 48 conterminous states. Each sample segment is divided into tracts which are delineated on photographs. A tract is a parcel of land within a segment under one management.

To accommodate simultaneous application of the open and closed segment concepts, two questionnaires are used. These concepts are delat with below.

The farm questionnaire is for operators who live within the boundaries of a sample segment. The other is called a tract questionnaire and is for tracts which have operators living outside the segment. The farm questionnaire provides for application of the open segment concept by getting data for an operator's entire farm disregarding its location with respect to the segment boundaries. Data on a farm basis are collected and summarized for livestock, chickens, agricultural labour, farm population, and size and type of farm.

Under the closed segment concept data are collected fro crops, land use, livestock and chickens. For operators living within the segments the farm questionnaire also provides for getting data for their land (tracts) that falls within the segment boundaries. For operators living outside the segment the tract questionnaire is designed to get data for tracts of land within the segment they operate. Thus it is possible to add tract data together to obtain the segment totals needed under the closed segment concept.

Use is made of an area sample supplemented by a sample selected from a list of operators of very large farms. The area sample is single-stage, stratified random. It consists of nearly 17 000 area sampling units (segments), which is approximately 0.6 per cent of the total land area. The average segment contains 1.3 farm operators and about 480 acres. IN areas where most of the land is cultivated, the average size is about 300 acres. In some regions where very little of the land is cultivated and is either non-agricultural or used primarily for grazing cattle or sheep, the sample segments may average about 4 000 acres. Allocation of the sample to states has been arbitrary, taking into account the importance and diversity of agriculture within the states and a dual objective of both state and national estimates.

Boundaries of the sample segments are delineated on aerial photographs. These photographs are part of the materials supplied to enumerators who go to the segments and contact farmers to get the required information. On the photographs, all fields on land areas in each segment are outlined. The name of the crop or land use and its acreage are recorded. Account must be taken of all land within each segment. The area of a segment is determined by planimetry of the aerial photograph.

The preceding paragraph describes the operation of the "closed" segment definition of a sampling unit, which is not feasible for all kinds of data. When farms must be used as reporting units the "open" segment concept is applicable and is applied in one of two ways: (a) enumerate all farms which have any part of their land in a sample segment and introduce a weighting factor for each farm such as the proportion of its land which falls within the boundaries of the segment; or (b) enumerate all farms with headquarters within the boundaries of a sample segment. The latter involves the definition of a unique point (headquarters) for each farm as the criterion for determining whether a farm is in the sample.

The June survey is conducted annually. A sample of about 16 000 tracts selected from the June survey comprises the area frame for the December survey. The December survey is designed to obtain livestock and poultry inventory numbers, births, deaths, and slaughter; and acreage seeded to winter wheat and rye.

A new sample of segments is not selected each year. About 80 per cent of the sample is retained from the previous year. This provides a ratio estimate from the identical segments. About 20 per cent are new segments each year to provide respondents relief after about five years of being surveyed.

The June enumerative survey data are collected during a two-week period in late May and early June. The reference period for crop acreages relates to a crop season.

For national and regional estimates the relative standard errors range from 2 to 4 per cent for major items; for state estimates, upward from 5 per cent.

The Economic Statistics and Cooperative Services have 42 field offices reponsible for the collection of agricultural statistics. For the June survey, a statistician is given the assignment of state supervisor. Usually one or more additional statisticians are designated as assistant state supervisors. An assistant state supervisor is usually promoted to state supervisor after one or two years of experience. The state supervisors are responsible for hiring, training and general supervision of enumerators and all aspects of the survey both in the state office and in the field.

The state supervisor and his assistant attend a regional training school about one month to six weeks prior to the survey period. Following the regional training school, each state office conducts one or more training schools for enumerators and supervisors. This occurs just prior to the start of the enumeration period.

June survey data are obtained through the use of 1 300 part-time enumerators and supervisors. There are approximately 200 supervisors and 1 100 enumerators. The receive two to three days training, depending on experience. Their training consists of such topics as the need for the data, how to read aerial photographs and locate the areas of enumeration, interviewing techniques, content and completion of each questionnaire, and the use of administrative forms. Actual field practice is used near the conclusion of the training school to provide enumerators the experience of interviewing a respondent.

Enumerators who have done an outstanding job over a period of years may be selected as supervisors. They review the work of about six enumerators early in the survey and observe such techniques as interviewing characteristics of the enumerator, probing methods used, accuracy in completing questionnaires and work progress. Also, supervisors are used to interview large farm operators on the lists, difficult respondents, and provide assistance when an enumerator quits or is having difficulties completing work assignments.

Qualifications for enumerators generally consist of knowledge of agriculture in his area, availability to work nearly full time during the survey period, high school education, desire to work with people and be receptive to the technical training required. Many of the enumerators are women. In the early phases of enumeration, a period of direct field supervision of enumerators is made by the state supervisor, assistant state supervisor and supervisory enumerators. The state supervisor and his assistant then return to the state office to review completed questionnaires.

Survey data are keypunched onto cards in the state offices and these punch cards and questionnaires are mailed to Washington, D.C. Summarized data are returned to the respective state for use in making state estimates.

ANNEX 3

"ASSESSMENTS" IN CURRENT AGRICULTURAL STATISTICS FOR DEVELOPING COUNTRIES

by

P. DELORME

Preface

The statistician often feels torn between the perfectionism of the statistical theorists who endeavour to plit hairs in estimation procedures, and the empirical simplicity of the methods he adopts in his daily work.

The result of this contrast is that the methods referred to as "eye estimates, expert opinion, assessments, etc." are felt by the statistician to constitute a last resort. Only direct statistical observation seems to him to offer the guarantees of reliability proper to exact sciences. Yet no one is unaware of the financial and psychological limitations of such observation.

- Financial, because direct statistical observation, even by sampling, is very expensive and can never be extended to cover all the economic and social data necessary for economic policy, planning, research, etc.

- Psychological, because direct observation very frequently comes up against resistance and refusal by the people who are the subject of the inquiries. Economic rivalry between officials, a liking for secrecy, fear that the data collected will be used for repressive purposes, make it impossible to obtain certain quantities by means of sincere statements.

Faced with these obstacles, the statistician is forced to follow circuitous routes which are less expensive and which avoid the obstacles presented by reticence. By making the best use of the data available, he attempts to build up the missing data (in national accounts it is not possible to leave any item blank). His method of working resembles that of the detective who tries to reconstruct an event on the basis of fragmentary indications. Every type of information is then worth taking, whether secondary sources (by-products of administrative activities, management, etc.) or assessments made by people with a thorough knowledge of the field studied, even if this knowledge is not the result of an ordered and controlled process of data collection and processing (this being what is known as eye estimates or expert opinion).

The purpose of this note is to rehabilitate a little these indirect assessment methods for current agricultural statistics in the developing countries and to draw attention to some principles which could improve the quality of these methods.

We must first reach agreement on vocabulary. The word "estimate" has specific connotations connected with its use in mathematical statistics. We shall therefore reserve it for procedures based on statistical theory, and use the term "assessment" for all the other methods (eye estimates, expert opinion, indirect methods, ...).

1. Introduction

In the developing countries, current agricultural statistics are a permanent requirement. By current agricultural statistics we mean annual statistics on the area and production of crops, livestock numbers and the output of animal products. This means that we are deliberately adopting a very restrictive definition. One could legitimately add statistics on agricultural population, utilization of fertilizers, etc.

Current agricultural statistics are not prepared for a specific purpose and in most cases do not lead directly to action, although in certain cases, and despite the fact that they are not produced with sufficient rapidity, they may make it possible to determine the consequences of particular events (climatic, for example) and thus trigger off specific actions. But we shall give a more accurate picture of these statistics if we say that they contribute to the knowledge and description of a country in the same way as geographical or soil maps, population statistics, climatic data, etc. They are not statistics connected with specific operations, like the surveys undertaken as part of pre- or post-project studies. They do constitute, however, the backcloth essential for making a sensible choice of the subjects and sites for development activities. They make it possible to perceive the fundamental balances between population, food production and food consumption, and measure the capacity of the country to export agricultural products.

The methods used to produce current agricultural statistics very often consist of what has been referred to in the preface under the general term "assessments" (eye estimates, expert opinion, etc.).

For a long time it has been thought that objective statistical surveys would be able to replace these archaic methods, and considerable progress has undoubtedly been made. But, as we shall see below, this target is still far from being achieved.

It may therefore be time to lift the veil of approbrium that covers these methods and to consider whether the statistician might not be able to coexist with them in peace without having the impression of having made a pact with the devil: an active coexistence, it goes without saying, because the aim is definitely to improve their quality.

2. The Role of "Assessments" in Agricultural Statistics

In agricultural statistics, as in the other areas, data can be classified into three categories according to the way in which they are produced:

1 - Results of surveys conducted for statistical purposes (censuses or sample surveys)
2 - By-products of administration, accounting, management, research, etc.
3 - Eye estimates and expert opinions.

This third category is admitted only with reluctance, yet it continues to be frequently used, as will be gathered from the figures below, drawn from an FAO report which reviews the agricultural statistics relating to a number of countries.

Of 120 countries examined, 80 use eye estimates for areas under wheat and maize, 74 for livestock numbers and 94 for milk production.

Consideration of the food balance sheets drawn up for certain products reveals the following facts. Each balance sheet consists of seven data (production, industrial

consumption, sees, etc.). For 14 countries producing wheat, the balance sheets contain 14 x 7 = 98 data; of these 98 data 69 are direct estimates by FAO!!! For maize the ratio is 170:224, and for rice 128:200. The other figures are supplied by the countries, but two-thirds prove to be eye estimates.

In 18 European countries, 294 statistical operations have been scrutinized. The breakdown is as follows:

- 17 surveys with physical measurements
- 77 surveys by interview
- 55 mail surveys
- 145 secondary sources.

The category of secondary sources is a real mixture. It includes both authentic administrative surveys producing a statistical by-product, but also assessments which the statistician prefers to call secondary sources when it is not he himself who makes them.

The unavoidable conclusion is that even in the European countries which devote considerable funds to agricultural statistics, assessments still have a role to play. In France, for example, although the total annual cost of agricultural statistics is about 60 million francs (including the permanent staff), a by no means negligible proportion of the figures in the agricultural statistical yearbook still consist of assessments. This is quite normal; and it is even more normal for the developing countries where the cost of statistical surveys is higher than in the developed countries, owing largely to transport difficulties.

The statistician must therefore learn to live with these assessments. He should not just resign himself to tolerating them like an incurable leper, but should take an interest in them as constituting an integral part of statistical work.

The political authorities, moreover, are much less scrupulous in this respect. Here, for example, is the statement made by a planning minister: "you statisticians never stop elaborating your data. When I need figures I send my expert to the region which interests me for 15 days and he brings back everything I need."

While such "experts" flourish, it will obviously be difficult to obtain financing for statistical surveys. For the shortage of statistics is by no means apparent. There would even seem to be an excess of figures, given the facility with which they can be invented where they do not exist. And it is precisely here that certain assessments are to be condemned when they fall outside the bounds of intellectual honesty.

Since assessments form part of the statistician's world, he must make an effort to improve them: to improve and not to suppress them, this latter objective appearing to be unattainable. The development of statistical surveys constitutes the royal road to the improvement of assessment. This point is restated here emphatically in order to avoid the rest of this note being interpreted as a return to obscurantism. But it must also be clearly stated that for the reasons indicated in the preface, it is not possible to collect through statistical surveys all the information necessary for knowledge of the agricultural sector, not even for the part we have called "current agricultural statistics".

Surveys constitute only one sector of statistical knowledge, extensive though one may hope this sector will be. What is important is that surveys and other assessments should

not constitute two separate worlds that ignore each other's existence. On the contrary, comparisons and synthesis should be systematically encouraged in order to arrive at the idea of the best possible estimate in the light of the information available.

In the following pages we shall speak very little of statistical surveys, but rather of assessments, considering how they could be improved at little cost through the training of enumerators, methodological reflection and better mobilization and utilization of existing information.

3. Examination of the Criticisms made of "Assessments"

To start with, we shall examine the criticisms made of data derived from "assessments". For this we shall use the course given at ENSAE by Mr. KLATZMANN, entitled "Course on the use of agricultural statistics". A number of examples are quoted in this course, and the fact that they are taken from French agricultural statistics of the fifties does not make them any the less generally applicable. But we shall concentrate mainly on deducing from these criticisms some rules for improving the quality of assessments.

1st criticism: The existence of several figures supposed to refer to the same fact.

Mr. KLATZMANN quotes the example of milk production in France: "While the Ministry of Agriculture assesses this production at about 180 million hectolitres for 1955, there is reason to think that actual production was in the region of 220 million hectolitres and perhaps even more." This sentence means that one is faced with two different assessments of the same milk production. Mr. KLATZMANN seems to think that the second is decidedly better than the first, but does not indicate why.

Another example of the same kind is given by Mr. THEODORE in his work: "Agricultural statistics in the developing countries". He gives three series of assessments supposed to represent rice production in Viet Nam.

It is common for the statistician to be faced with several divergent figures. But this is a situation which he should not tolerate as a matter of course. The differences must be explained, judgements made and syntheses effected. Assessment methods must benefit from these judgements and syntheses so that the reasons for divergence can be eliminated at their source. This work is indispensable and it can be seen that many study reports (studies on projects, etc.) consist to a large extent of a compilation of divergent figures which it is endeavoured to reconcile in a final synthesis. It would be better for these judgements and syntheses to be undertaken at the source by the statistical services. In this respect national accounts constitute a constrictive framework making syntheses obligatory. In agricultural statistics food balance sheets should play a similar role. Although it may be permissible for crude survey data to show some discrepancies with other figures, a document such as a yearbook of agricultural statistics, must really correspond to the concept of "the best possible estimate in the light of all the information available".

2nd criticism: Inconsistency between different figures.

a) Inconsistency in time series

Time series obtained by assessments may show completely abnormal jumps. Mr. KLATZMANN quotes the example of a French department in which the value per hectare of vegetable crop

yields abruptly increased four-fold from one year to the next. The reason was that the yield assessments made by the Agricultural Services Division were revised without this fact being mentioned in the figures published. Breaks of this kind can also be explained in some cases by changes in definitions and concepts.

b) Logical inconsistencies

Mr. KLATZMANN quotes the uhlikeliness of a figure of 100 industrial cider-mills alleged to exist in a department which produces almost no cider apples. He also quotes the case of a department in which the ratio between the number of chickens produced and the number of laying hens seemed to be ten times higher than the average for France as a whole. These inconsistencies derive either from faulty interpretation of the definitions or lack of precise definitions, or rather from a total lack of understanding of orders of magnitude on the part of the people who produce the asessments.

Some rules for improving assessments can immediately be deduced:

- define very precisely the concepts, definitions and conventions on the basis of which the assessments should be made;
- carry out as many cross-checks as possible in order to identify and eliminate inconsistencies;
- explain and justify any abrupt variations occurring in a time series and appreciable differences between zones with similar characteristics from the point of view of geography, climate and population.

4. Errors Affecting "Assessment"

We must first examine the notion of bias or systematic error in estimation and assessment procedures. Consider estimate $\bar{z}$ of unknown value z which is to be measured. We shall suppose that this estimate is arrived at by a random mechanism which can be repeated to yield other estimates of the same probability law. The deviation of $\bar{z}$ from z is therefore a random variable. $\bar{z}$ is said to be unbiased if the expected value of the deviation $(\bar{z} - z)$ is zero. But this property is of practical interest only if the procedure is indeed repeated. The absence of bias is then a guarantee that the basic principle of statistics, the offsetting of errors, will work when the random mechanism is repeated. This point is particularly important when summing estimates (grouping of geographical regions, for example) obtained by such a random mechanism.

If, on the other hand, the random mechanism functions only once to produce a single estimate of an unknown value, the concept of bias loses interest. The important thing is the existence of a deviation between the true value and its estimate. As a matter of fact, the simple statement that a number is the "estimate" of an unknown implies an assumption of no bias. Using a Bayesian approach, we would associate this estimate with a probability distribution in which the true value would be considered as a random variable with a distribution centred on the estimate.

To say that an estimate is biased without being able to indicate the direction of the bias is meaningless and does not add any information.

To say that an estimate is biased and to know the direction of this bias constitutes a supplementary item of information which immediately makes it possible to correct the initial

estimate. If, for example, the bias is positive, any number slightly inferior to the initial estimate will be a better estimate.

One thus arrives at the concept of a subjectively unbiased assessment, that is to say, such that the person producing the assessment is aware of the existence of a probable deviation between this figure and the true value, but can say nothing regarding the direction of this deviation.

Every assessment is the result of an abstract mental process which generalizes from partial information. Information is recorded, consciously or not, in the memory of the operator and extrapolated to produce the assessment.

It is therefore possible to distinguish between:

- technical errors due to quantitative and qualitative shortcomings in the information collected and to faulty extrapolation;
- systematic errors resulting from a more or less conscious desire to produce assessments pointing in a predetermined direction.

Let us give a few examples of these two types of errors:

a) "Technical" errors

- the observer sees a calf with 5 legs and extrapolates this to the entire species (a calf is an animal with 5 legs) or to a zone (the calves in the region have 5 legs);
- an agricultural instructor questions the farmers he meets regarding the coffee they have harvested and from the replies obtained deduces (extrapolates) an assessment of the development of coffee production in this zones. But the farmers he meets most frequently are precisely those who are in contact with him for plant health treatments, utilization of fertilizers, etc., hence those who obtain the best yields.

b) Systematic errors

- an agricultural instructor who wishes to demonstrate the quality of his work will be tempted to increase deliberately the production estimates for his sector or will base himself on figures calculated in advance as the target of a development plan;
- a livestock buyer questioned regarding prices will tend to over-estimate them: for him, they are always too high. For the seller, the distortion will be in the opposite sense.

Systematic errors pose the problem of the neutrality of the person making the estimates with respect to the quantities to be estimated - a problem all the more difficult in that the absence of neutrality is often unconscious. This is essentially a problem of education and training to ensure observance and application of the statistician's basic ethics (detachment and neutrality of the observer with regard to the event observed).

Systematic distortions can also be minimized by arranging confrontations between people likely to produce assessments distorted in opposite senses. This is what is usually done for price assessments, when sellers and buyers are brought together in quotation commissions. This reproduces on a reduced scale the bargaining in which the two categories have engaged, leading to an assessment of the average price actually prevailing.

Reduction of the errors we have referred to as technical also depends to a great extent on training those responsible for making the assessments. And the best possible training is for them to take part in effecting and processing the results of objective statistical surveys.

We have seen that any assessment is the result of processing by the operator's brain of partial information stored in the memory. One may therefore hope to improve the quality of assessments by systematizing somewhat these abstract processing procedures.

The information could be stored by being written in a notebook which the operator would carry around with him. In this book the operator would record in summarized form the information collected (farmers' opinions, measurements taken in the fields, facts noted in the market, etc.).

Utilization of this information for the purpose of making assessments presupposes the ability to replace them in the environment which has to be described, that is to say, to extrapolate them with discernment. This in turn presupposes sufficient knowledge of the zone to be able to undertake explicit (by calculations) or implicit (by reasoning) weightings. And it is at this stage that previous experience in objective surveys proves most useful.

The operator must also take the trouble to increase the amount of information collected by questioning the greatest possible number of farm workers and other people in the zone, measuring yields, etc.

Finally, the assessment should be made, not by a single individual, but by a small group, in order to eliminate as far as possible the more or less conscious systematic distortions connected with the personality of the individual producing the assessments.

5. Some Principles for Improving Assessments

We shall now endeavour to recapitulate and complete the preceding remarks in the form of a few principles calculated to improve the quality of assessments.

Principle No. 1: Confine assessments to the smallest possible geographic area

Assessments should be made in zones sufficiently small to make possible real physical contact and hence exchange of information between the person or persons making the estimates and the people or things within the zone observed. The zone observed transmits information. The person moving within the zone receives that part of the information which comes within range. The amount of information received during a period of time depends on the estimator's course. The smaller the zone, the greater the chance that each point in the zone will lie within range of this course and hence be included in the estimator's field of observation. If the zone is small information can be picked up from most of the zone's area. The quality of the assessments should thus be improved.

To this intuitive argument regarding the connection between the area of the zone observed and the quality of the assessments, can be added another regarding the quality of geographical summaries.

It can be shown, in fact, that under fairly general hypotheses the quality of the assessments obtained by aggregating the assessments for the elementary zones is better the higher the number of zones.

Principle No. 2: Train "assessors"

We have repeatedly emphasized the necessity for this training and the fact that participation in statistical surveys constitutes a most important aspect of this formation.

By virtue of the first principle we have just stated, for assessments reliance must be placed on agents working in the smallest possible geographical units. From this point of view the local officers of the Ministry of Agriculture offer the advantage that they usually control much less extensive zones than the other administrative divisions of the country (agricultural sectors, agricultural stations, etc. - the terminology varying according to the country).

These officers, owing to their responsibilities in the field of extension work or the control of certain products, have to travel throughout the zone they control. They are therefore unquestionably in the best position to undertake assessments for current agricultural statistics.

It is therefore with these officers in mind that we shall now list the main subjects that should be comprised in their training:

a) Thorough study of their zone, including mapping of its boundaries, calculation of its area, details on its contents (list of villages and population) and more generally a summary of all the data it has already been possible to collect on the zone.

b) Study of certain rules: the agents should be well acquainted with certain orders of magnitude and certain frames of reference (per capita consumption, yields, area cultivated per person, etc.) which will enable them to test the probability of their own assessments.

c) Organization of data collection: the information collected haphazardly during their journeys, meetings, conversation, etc., whether of a qualitative or a quantitative nature, should be recorded in a sort of log-book so that it can later be sorted and suitably processed (avoiding crude extrapolations, for example).

d) Study of the definitions and concepts used in current agricultural statistics (cf principle No. 6).

e) Study of sampling methods and extrapolation procedures. This consitutes real statistical training and will not be effectively assimilated unless the agents have the opportunity to participate personally in statistical surveys, at both the collection and the processing stages (hence the importance of manual processing as a training aid).

f) Acquisition of the ability to visualize units of measurement. Areas and quantities are estimated with reference to a standard: hectare, kilo, etc.

These units of measurement must present a definite image for the officers carrying out assessments. This is precisely the meaning of the term "eye estimates". On looking at a field, one must be able to assess its area in hectares. On looking at a bowl of millet or groundnuts, one must be able to indicate its approximate weight.

This is not a question of flair, but derives from training techniques that can be summarized as follows. First, the person looks at a field and assesses its area. The field is then measured and the result stated. Numerous repetitions of this operation produce the required effect and the units of measurement acquire a concrete image in the mind of the person concerned.

Principle No. 3: Assess variations and not absolute values - base year

It is easier to perceive variations (for example, between one year and the preceding one) than absolute values. Realization of this fact leads to the idea of taking economic calculations as the model for assessments: that is to say, establishing assessments in absolute figures for a base year. This base year should be better supplied than others with data emerging from statistical operations (for example, results of an agricultural census). For this base year consistency between all the figures available should be ensured within each small zone, thus making it possible to reach the best possible assessments in the light of the information available. The figures thus obtained for the base year should serve as the starting point for the assessments, which will now be made only through appraisal of the annual variations or, at the very least, will be systematically compared with the figures for the previous year.

Principle No. 4: Search systematically for data able to strengthen or support the assessments

a) Data on the zone

In the zone itself, certain data may exist or be easy to calculate:

- area of the zone, obtainable by marking out the boundaries of the zone on a map and plotting;
- total population of the zone, using the data from administrative censuses combined with a list of the villages situated in the zone;
- data emerging from statistical surveys, even old ones (demographic, consumption budget, agricultural or others);
- data provided by the activity of administrative or other bodies working in the zone. For example, the development projects whose activities affect the zone very often possess figures which they have had to collect for their own requirements;
- data from special studies carried out in the zone (village monographs, for example);
- data provided by research bodies situated in the zone. Plant production research stations often have experimental fields and thus possess data on yields.

b) Data not coming from the zone

Certain parameters are sufficiently stable in space and time to make it possible to resort in certain cases to measurements and observations made outside the zone.

But it will obviously be preferable to use measurements made in a zone which has close analogies as regards climate, physical conditions, population, etc. Thus data relating to yields, food consumption, area cultivated per person may in a first approach be taken from other geographical zones with similar characteristics, provided there is a prior critical examination.

Use must also be made of data available at a wider geographic level than the elementary zones in which the basic assessments are made. For example, administrative bodies (price stabilization funds, cooperative unions, etc.) often possess data valid for the whole country or for large regions, but not available for the small elementary zones. It is necessary, however, to ensure consistency between the zone assessments and overall figures. Hence the necessity of links between the different geographical levels leading to successive corrections. These corrections can, moreover, be formalized by using the least squares method.

Principle No. 5: Look for connections between the quantities estimated

Assessments referring to different quantities must be systematically compared with each other. For this purpose one can calculate the ratios between certain quantities (area cultivated per person, per capita consumption, etc.), which will make it possible to detect any inconsistencies. One can also use the relationships that the assessments should verify in order to improve the latter's quality. Food balance sheets can play an important role in this respect.

Principle No. 6: Harmonize and clearly define concepts and nomenclatures

It might be assumed that it is useless that it is useless to define precisely the differences between standing crops, harvests, farm production, etc., if these quantities can be estimated only to within 20 or 30 per cent. Such reasoning is mistaken. It is like claiming that a mediocre archer can do without a target.

On the contrary, one must define with precision what one is trying to assess. Only thus are geographic summaries justified. It is these definitions which illuminate the comparisons between a number of figures and which make it possible to organize the statistical surveys intended to ground the assessments on objective observations.

This is why one of the first reforms to be undertaken in order to improve the quality of assessments is the preparation of adequate forms on which to record them, accompanied by precise instructions on the meaning of the various concepts used. These forms must be identical throughout the territory in order to facilitate aggregation.

6. Conclusion

When the statistician, in the privacy of his workshop, compiles, deciphers, traces, amalgamates, compares, breaks down, rectifies, analyses, synthesizes, improves, corroborates, detects, stratifies, intrapolates, extrapolates, interpolates, retropolates, corrects, balances, adjusts, subtracts, extracts, infers, induces, completes, collates, correlates, computes, imputes, he is doing what he himself often calls his cooking. This analogy with the gastronomic art, far from being pejorative, shows, on the contrary, the importance of thethe subtle blending the statistician must undertake in order to achieve his purposes and serve the customer with a dish of acceptable figures.

For current agricultural statistics the recipe we have worked out can be summarized as follows: a good portion of assessments, a portion of statistical surveys, another portion of data emerging from administrative activities; stir well with the generalized least squares and serve on glossy paper in a yearbook of agricult-ural statistics.

The principles we have tried to deduce also have consequences for the method of organizing agricultural statistics.

We have seen that the field officers of the Ministry of Agriculture are in the best position to undertake the assessments which form an important part of current agricultural statistics. The corollary of this is the institutional responsibility of this Ministry with regard to agricultural statistics. It also means that the programme of statistical inquiries must be conceived around these officers. Too often there is a temptation to draw up an ambitious programme intended to satisfy very different requirements by means of full-scale statistical surveys. The cost of such programmes is rarely compatible with the country's real financial capacities.

By contrast, the methodology underlying the subjects treated in this note consists in relying at the outset on what exists, that is to say the field officers of the Ministry of Agriculture, and ascertaining how much time they can devote yearly to agricultural statistics bearing in mind their other tasks. On the basis of this parameter a modest but realistic and progressive programme of work can be formulated, organized around the system of assessing the annual data for current agricultural statistics and strengthening this by local statistical observations (yield measurements by sample crop cutting, maintenance of village registers, observation of certain prices, area measurements, etc.).

ANNEX 4-A BENIN

Rapport Mensuel sur le Développement de la Campagne Agricole

Mois de : 197

CARDER : ..... DISTRICT : .....

Secteur : .....

Nom du Chef de secteur ou du Responsable à la Production : .....

I.- Pluviométrie : Au dessus de la normale ☐ Normale ☐ En dessous de la Normale ☐
(mettre un X dans l'une des cases)

2.- Distribution ou vente de semences sélectionnées au cours de ce mois

Produit	Prévision (1)	Qté distribuée (kg) au cours de ce mois	Qté distribuée (kg) Cumulée (kg) (2)

Produit	Prévision (1)	Qté distribuée (kg) au cours de ce mois	Qté distribuée (kg) Cumulée (kg) (2)

3.- Distribution ou vente d'engrais au cours de ce mois

Type d'engrais	Prévision (1)	Qté distribuée (kg) au cours de ce mois	Qté distribuée (kg) Cumulée (kg) (2)

Type d'engrais	Prévision (1)	Qté distribuée (kg) au cours de ce mois	Qté distribuée (kg) Cumulée (kg) (2)

4.- Distribution ou vente de matériel au cours de ce mois

Type de matériel	Prévision (1)	Qté distribuée au cours de ce mois	Qté distribuée Cumulée (2)

Type de matériel	Prévision (1)	Quantité distribuée au cours de ce mois	Quantité distribuée Cumulée (2)

(1) - Quantité prévue dans le Plan de Campagne pour le mois en question.

(2) - Depuis le début de la campagne agricole en cours.

5.- Avancement des travaux agricoles (Compte tenu du Plan de Campagne)

Produit	Mettre un X dans les colonnes 2 à 11 selon le cas											Spécification	Observations
	Préparation du sol		Semis		État des cultures			Prévision de Récoltes					
	Selon le calendrier	En retard (1)	Selon le calendrier	En retard (1)	Satisfaisant	Moyen	Mauvais (1)	Bonne	Moyenne	Mauvaise (1)	Estimation de cette récolte(T)		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sorgho												en grain	
Maïs												"	
Riz												décortiqué	
Manioc												Tubercule	
Igname												"	
Haricot												fève	
Arachide												décortiquée	
Coton												graine	
Autres (spécifier)													

(1) Indiquer brièvement les causes :

C- AGRICULTURE

1ère saison ☐
2è saison ☐
les 2 saisons ☐

Cocher l'une des cases suivant le cas.

1- Principaux produits cultivés dans le village :

.....

2- Rotation et principales associations

1ère année :.....
2è année :.....
3è année :.....
4è année :.....

3- Nom de l'unité ou de la mesure dans laquelle on exprime la superficie dans le village : .....

son équivalence en ares :..... ☐☐☐

4.- Superficie cultivée dans le village :

4.1.- Superficie totale : en mesure locale: ☐☐☐ en ha: ☐☐☐

dont :

4.2.- Par les villageois : en mesure locale: ☐☐☐ en ha: ☐☐☐

4.3.- En champs Communautaires : en mesure locale: ☐☐☐ en ha: ☐☐☐

En champs Communautaires indiquer les cultures pratiquées

1) ..... en mesure locale: ☐☐☐ en ha: ☐☐☐

2) ..... en mesure locale: ☐☐☐ en ha: ☐☐☐

3) ..... en mesure locale: ☐☐☐ en ha: ☐☐☐

4) ..... en mesure locale: ☐☐☐ en ha: ☐☐☐

5.- Superficie cultivée suivant les produits

Superficie exprimée en mesure locale ☐ ares ☐ (Cocher l'une des cases)

D- PRODUCTION

Produits	Rdt Kg/ha	Mesure Locale		Equivalent en Kg de		Etat du produit
		Nom	Nombre récolté	La mesure	La production	
Maïs						Grain
Riz						Paddy
Sorgho						en Graine
Manioc						Tubercule
Igname						Tubercule
Haricot						Décortiqué
Voandzou						Décortiqué
Goussi						
Tomate						Unité
Arachide						Décortiqué
Coton						en Graine
Autres (spécifier)						

E- COMMERCIALISATION

Produits	Mesure loc.		Equivalent en kg
	Nom	Nbre	
Maïs			
Riz (Paddy)			
Sorgho			
Manioc			
Igname			
Haricot			
Arachide			
Coton			
Autres (spécif.)			

Crédit Agricole (indiquer)
Le mentant du crédit accordé :
(frcs)

Le montant recouvré:.....:

F- Effectif du matériel du 31/12/192....

Matériel	Désignation	Nbre ou quté existant déjà (en 31/12/19..)	Aquisition du 1/1/19.. au 31.12.19..	Perte ou réforme	Total au 31/12/19..
Engrais					
Insecticide					
Charrues	unité				
Charrettes	"				
Roulettes	"				
Pulvérisateur	"				
Sémoire	"				

ANNEX 4-B FAO

Proposed Crop Reporting Form

AGRICULTURAL CYCLE.....

YEAR .....

IDENTIFICATION OF AREA

PROVINCE .....
DISTRICT .....
....
....

CROP NAME
or
REPORTING DATE

DATE OF ROUND OR NAMES OF CROPS	A R E A OF C R O P								I N P U T S					
	IRRIGATED				NOT IRRIGATED				SEEDS		FERTILIZERS		PESTICIDES	
	Ordinary Seed		H.Y.V. Seeds		Ordinary Seeds		H.Y.V. Seeds		Volume of Ordinary	Volume of H.Y.V.	Type	Volume	Type	Volume
	With Fert.	Without Fert.	With Fert.	Without Fert.	With Fert.	Without Fert.	With Fert.	Without Fert.						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

AGRICULTURAL TECHNIQUES					L O S S E S						CROP CONDITIONS		EXPECTED HARVEST		
Type of Preparation of Soil	Sowing or Planting		Type of Plant Care	Method of Harvesting	Natural Calamities			Pests + Diseases			In Absolute Terms	Comparison with previous year	Area	Yield	Production
	Type	Date			Type	Area Affect	% Loss	Type	Area Affected	% Loss					
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

ANNEX 4-C FAO

Schedules on: List of Parcels and Fields
Field Questionnaire
Crop Densities Questionnaire
Crop Yield Questionnaire

FAO-UGANDA EXPERIMENTAL CENSUS OF AGRICULTURE

Region BUGANDA
District MENGO
County KYADONDO
Gombolola SABAWALI
Parish MUNYUKA

Enumerators: _____
_____
_____
_____
_____

Date _____

VI. LIST OF PARCELS AND FIELDS

Name of Holder _____

Holding No: [ ][ ][ ]

Serial No. of Parcel	Location	Land Tenure	Serial No. of field	Year of Clearing	Crops	Solo or Mixed	Crops planted in previous season	Crops expected to be planted in next season
1	2	3	4	5	6	7	8	9

FAO-UGANDA EXPERIMENTAL CENSUS OF AGRICULTURE

Region BUGANDA
District MENGO
County KYADONDO
Gombolola SABAWALI
Parish MUNYUKA

Enumerators: _____
_____
_____
_____
_____
Date _____

VII. FIELD QUESTIONNAIRE

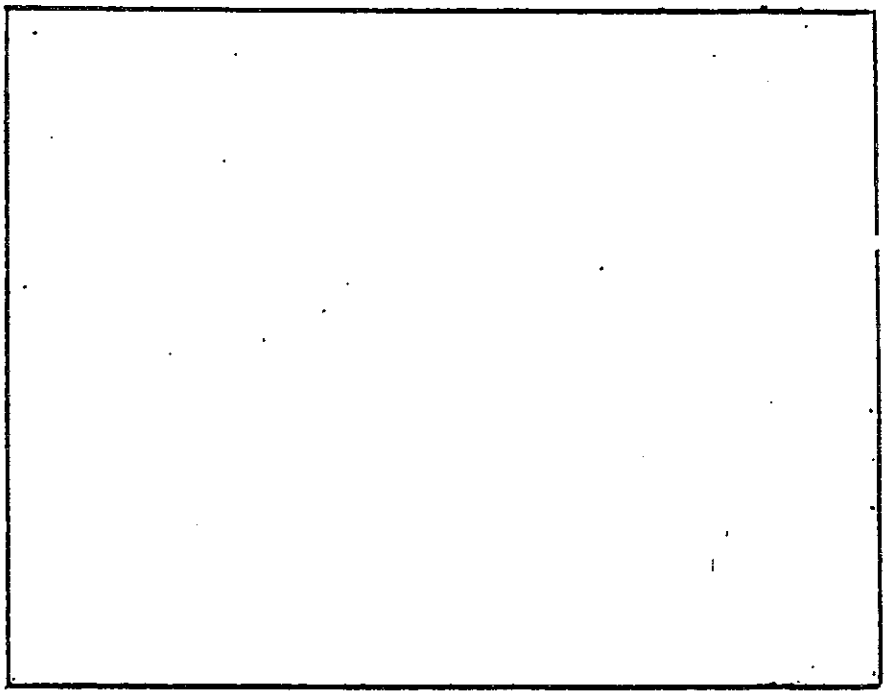
1. Name of holder _____ 2. Holding No. ☐☐☐
3. Field No. ☐☐☐ 4. Declared Area _____
5. Year of clearing 1 9 ☐☐ 6. First Year of planting 1 9 ☐☐
7. Fixed cultivation ☐ 8. Crops grown _____
or shifting cultivation ☐ in previous year _____
9. Irrigation 1. YES ☐ 0. NO ☐ 10. Type of manure: kraal ☐
green ☐
compost ☐
none ☐
11. Fertilizers 1. YES ☐ 0. NO ☐
12. Anti-erosion practice 1. YES ☐ 0. NO ☐
13. Insecticides or pesticides 1. YES ☐ 0. NO ☐
14. Crops grown in the field

Name of Crop	Improved seeds	Date of Sowing or planting	Expected date of harvesting
14.1	14.2	14.3	14.4

15. Tree crops planted on border or disseminated

Name	Number in producing age	Number Non-producing
15.1	15.2	15.3

16. Rough sketch of field



17. Field measurements

Scale: 1" per _____

Name of side	length in feet	Bearing	Inclination	Corrected length	Length in scale
17.1	17.2	17.3	17.4	17.5	17.6

FAO-UGANDA EXPERIMENTAL CENSUS OF AGRICULTURE

Region BUGANDA
District MENGO
County KYADONDO
Gombolola SABAWALI
Parish MUNYUKA
Village _____

Enumerators: _____

Date _____

VIII. CROP DENSITIES QUESTIONNAIRE

1. Name of holder _____ 2. Holding No. ☐☐☐

3. Field No. ☐☐☐ 4. Area of field _____

5. Semi-perimeter in paces _____

6. Last random number used: column _____ row _____

7. Random number to be used along perimeter _____

8. Random number to be used inside the field _____

9. Size of plot for density count _____ feet x _____ feet

10. Density count

Name of crop	Variety	Unit of count Plants or Hills	Number
10.1	10.2	10.3	10.4

FAO-UGANDA EXPERIMENTAL CENSUS OF AGRICULTURE

Region BUGANDA Enumerators: _____
District MENGO _____
County KYADONDO _____
Gombolola SABAWALI _____
Parish MUMYUKA _____
Village _____ Date _____

IX. CROP YIELD QUESTIONNAIRE

1. Name of holder _____ 2. Holding No. ☐☐☐

3. Field No. ☐☐☐ 4. Name of crop _____

5. Area of field _____

6. Semi-perimeter in paces _____

7. Last Random number used: column _____ row _____

8. Random number to be used along perimeter _____

9. Random number to be used inside the field _____

10. Size of crop cutting plot _____ feet x _____ feet

11. Number of plants or hills in plot _____ plants / hills

12. Number of plants or hills of the plot which have been harvested before arrival of enumerator

_____ plants / hills

13. Weight of crop harvested

time	State of crop	Weight in pounds and ounces
13.1	13.2	13.3
At harvest time		
After drying		
After processing		

ANNEX 4-D FRANCE

Utilisation du Sol au Course de la Campagne Agricole

1. IDENTIFICATION — APPARTENANCE AU CHAMP DE L'ENQUETE

N° d'identification RGA — Dép. | Comm. | N° ordre | N° fille

(PAGE A REMPLIR OBLIGATOIREMENT. RAYER LES BACS DES QUESTIONS SANS OBJET)

A — PREREMPLIR OU VERIFIER :

1.01. **Adresse postale ; téléphone**
mettre à jour si nécessaire l'ensemble de la carte 0 - Sinon barrer toute la carte 0

TC 0 — 12

13 CODE POSTAL 17 — 18 20 — 30 — 40 — 46

ADRESSE : NOM — PRÉNOM (S) * N° RUE, RUE, LIEU-DIT * COMMUNE * BUREAU POSTAL ÉVENTUEL SI DIFFÉRENT

47 50 — 60 — 70 — 79

*(Ne pas oublier les symboles séparatifs * entre les différents éléments de l'adresse.)*

TC 1 — 12

NUMÉRO DE TÉLÉPHONE ..... 13 — 20

1.02. **Catégorie de l'exploitation en 1975 :** 1 ha de superficie agricole utile = 1 ; 20 ares de cultures spécialisées = 2 ; autres seuils = 3 ; vacante = 4 21

Superficie agricole utile en 1975 ..... 22 ha 27 ares

B — REMPLIR SUR LE TERRAIN :

1.03. **Enquêteur : M.**.....
Date de l'enquête (jour - mois - an) ..... Jour Mois Année 28 — 33

1.04. **Le chef d'exploitation** vivait-il sur l'exploitation en 1975 ? Oui = 1, non = 0 34
→ **SI NON, REMPLIR UNE FICHE COMPLÉMENTAIRE (*)**

1.05. **Le siège** (= le bâtiment principal d'exploitation, s'il existe).
Où est-il situé actuellement ? (préciser en clair) { Département : ..... 35 ; Commune : ..... }
Etait-il déjà à la disposition de l'exploitation en 1975 ? Oui = 1, non = 0 40
→ **SI NON, REMPLIR UNE FICHE COMPLÉMENTAIRE (*)**

1.06. **Terres - Bâtiments** Depuis 1975 avez-vous perdu des terres ou bâtiments agricoles ? (ventes, mises en location, expiration d'un bail, etc.), Oui = 1, non = 0 41
→ **SI OUI, REMPLIR UNE FICHE COMPLÉMENTAIRE (*)**

1.07. **Fusion - Absorption.** L'exploitation a-t-elle absorbé depuis 1975 (ou fusionné avec) une ou plusieurs exploitations (création d'un GAEC, etc.) ? Oui = 1, non = 0. 42
→ **SI OUI, REMPLIR UNE FICHE COMPLÉMENTAIRE (*)**

1.08. **Seuils.** — L'exploitation a 1 ha ou plus de superficie agricole utile ..... = 1
— Non, mais elle a 20 ares ou plus de cultures spécialisées. ..... = 2
— Non, mais elle dépasse les seuils indiqués dans le guide d'instructions (1 reproducteur mâle, 1 jument, 1 vache laitière, 1 truie-mère, 6 brebis-mères, 6 chèvres, 5 ares de fleurs, 5 ares de maraîchage, 10 ares de vignes AOC, etc.)
Préciser ..... = 3 43
— Elle ne remplit aucune de ces 3 conditions (vacante ou disparue) ..... = 0
→ **SI RÉPONSE « 0 » REMPLIR LA PAGE FAMILLE DU CHEF ET ARRETER LE QUESTIONNAIRE**

(*) Si une fiche a déjà été remplie chez l'exploitation mère, on vérifiera sa validité chez les exploitations filles 1976

C — CONCLUSIONS. REMPLIR EN BUREAU (après examen du dossier et de la fiche complémentaire par le Service Départemental de Statistique Agricole).

1.09. **Position de l'exploitation.** Pérenne 76/75 = 1, fille 76 non vacante = 2, ex-vacante, nouvelle ex-nihilo = 3 disparue définitive = 4, vacante ou < seuils = 5, refus remplacé =6. 44

1.10. **Nombre d'exploitations filles 1976 de l'exploitation 1975.** 45

1.11. **Appartenance au répertoire des exploitations exceptionnelles** REX 75 = 1, nouvelle REX = 2, sinon = 0 47

1.12. **Stratification :** ..... { Coefficient d'extrapolation 1976 (T 76) ..... ; Numéro de sous-échantillon (10 à 89) 49 50

1.13. **Cas particuliers :** Introduction dans l'EPEXA : d'une REX = 1, nouvelle ex-nihilo = 2, Remplaçante : d'une Rex = 3, d'un refus = 4, changement de département = 5 51

1.14. **Remplacée** (Rex. Refus. changement de département) N° de l'exploitation de remplacement 52
Dép. | Comm. | N° ordre | N° Fille

1.15 **Contrôles de présence.**

Pollutions Utisol présence = 1 absence = 0	Rubriques régionales présence = 1 absence = 0	Chiptire chepiel présence = 1 absence = 0	Famille : No de lignes à perforer	Questionnaires spécifiques (présence = 1 absence = 0) Vergers	Salaires	Bovins	Porcins	Temps Partiel	Montagne	Céréales	Enquête Expérimentale	Enquête Locale	Fiche Complémentaire
63				70									77

DOC. EPEXA 76 - 1

2. UTILISATION DU SOL AU COURS DE LA CAMPAGNE AGRICOLE 1975 — 1976

(1er novembre 1975 — 31 octobre 1976)

Rayer les bacs sans objet (code et montant)

TC 2/12

PRÉVISIONS 1976 — 1977 FACULTATIF (Se conformer aux instructions du statisticien départemental)

CULTURES PRINCIPALES

CÉRÉALES (y.c. semences)	Code	Hectare	Are	Code	Hectare
Blé tendre	0,1,0			1,1,0	
Blé dur	0,1,1			1,1,1	
Orge (y.c. escourgeon)	0,1,2			1,1,2	
Avoine	0,1,3			1,1,3	
Seigle	0,1,4			1,1,4	
Mélanges	0,1,5			1,1,5	
Maïs grain (y.c. maïs semence)	0,1,6			1,1,6	
Riz	0,1,7			1,1,7	
Autres (sorgho, sarrasin, millet, etc.)	0,1,8			1,1,8	
TOTAL	0,1,9			1,1,9	

CULTURES INDUSTRIELLES					
Oléagineux (y c. semences) — Colza	0,2,0			1,2,0	
Oléagineux (y c. semences) — Autres (tournesol, navette, œillette, moutarde, lin oléagineux, soja, etc.)	0,2,1			1,2,1	
Lin textile, chanvre (textile et papier)	0,2,2			1,2,2	
Houblon	0,2,3			1,2,3	
Tabac	0,2,4			1,2,4	
Lavande et lavandin	0,2,5			1,2,5	
Semences graînières (légumes, fleurs, plantes industrielles et sarclées)	0,2,6			1,2,6	
Autres (chicorée à café, plantes médicinales, condimentaires, à parfum, etc.)	0,2,7			1,2,7	
TOTAL	0,2,9			1,2,9	

LÉGUMES SECS (y.c. semences)					
Haricots secs	0,3,0			1,3,0	
Fèves et féveroles en sec pour animaux	0,3,1			1,3,1	
Autres (pois secs, lentilles, etc.)	0,3,2			1,3,2	
TOTAL	0,3,9			1,3,9	

PLANTES SARCLÉES					
Pommes de terre — De conservation pour consommation humaine et (ou) animale	0,4,0			1,4,0	
Pommes de terre — Primeurs	0,4,1			1,4,1	
Pommes de terre — Industrie	0,4,2			1,4,2	
Pommes de terre — Plants	0,4,3			1,4,3	
Betteraves industrielles	0,4,4			1,4,4	
Betteraves fourragères	0,4,5			1,4,5	
Choux fourragers	0,4,6			1,4,6	
Autres (topinambours, carottes, navets et rutabagas fourragers, etc.)	0,4,7			1,4,7	
TOTAL	0,4,9			1,4,9	

CULTURES FOURRAGÈRES (y.c. semences)					
Prairies artificielles (luzerne, trèfle violet, etc.)	0,5,0			1,5,0	
Prairies temporaires de 5 ans et moins (graminées, mélanges de graminées, et légumineuses)	0,5,1			1,5,1	
Fourrages annuels (Cult. principale) — Maïs fourrage (consommé en vert, déshydraté ou ensilé)	0,5,2			1,5,2	
Fourrages annuels (Cult. principale) — Autres	0,5,3			1,5,3	
TOTAL	0,5,9			1,5,9	
JACHÈRES (y compris jachères de vignes et autres cultures permanentes)	0,6,9			1,6,9	
LÉGUMES FRAIS (y.c. asperges, melons, fraises) DE PLEIN CHAMP (cultures principales entrant dans l'assolement)	0,7,9			1,7,9	

TOTAL TERRES LABOURABLES → (à reporter page suivante)

	Code	Hectare	Are	Prévisions 76-77 Code	Hectare
report page précédente (terres labourables)					
LÉGUMES FRAIS EN MARAICHAGE (y.c. asperges, melons, fraises et champignons)					
Plein air (y.c. champignons en cave)	2,0,0			3,0,0	
Sous abri	2,0,1			3,0,1	
Sous serre	2,0,2			3,0,2	
TOTAL	2,0,9			3,0,9	
FLEURS ET PLANTES ORNEMENTALES (en culture principale)					
Plein air	2,1,0			3,1,0	
Sous abri	2,1,1			3,1,1	
Sous serre	2,1,2			3,1,2	
TOTAL	2,1,9			3,1,9	
VIGNES (y.c. jeunes plantations)					
Vignes à raisins de cuve — Vins de table (y.c. vin de pays)	2,2,0			3,2,0	
Vignes à raisins de cuve — V.D.Q.S.	2,2,1			3,2,1	
Vignes à raisins de cuve — Ap. d'origine contrôlée (AOC)	2,2,2			3,2,2	
Vignes à raisins de table	2,2,3			3,2,3	
TOTAL	2,2,9			3,2,9	
VERGERS 6 ESPÈCES (y.c. jeunes plantations) → QUESTIONNAIRE EVOLUTION DES VERGERS ?					
Abricotiers	2,3,0			3,3,0	
Cerisiers	2,3,1			3,3,1	
Pêchers — Chair blanche	2,3,2			3,3,2	
Pêchers — Chair jaune	2,3,3			3,3,3	
Pruniers	2,3,4			3,3,4	
Poiriers — d'été	2,3,5			3,3,5	
Poiriers — d'automne ou d'hiver	2,3,6			3,3,6	
Pommiers de table — Golden	2,3,7			3,3,7	
Pommiers de table — Autres	2,3,8			3,3,8	
TOTAL 6 ESPECES	2,3,9			3,3,9	
*Si total vergers non nul, aviez-vous des vergers en 75 ? NON → QUESTIONNAIRE EVOLUTION DES VERGERS ?					
AUTRES CULTURES PERMANENTES					
Agrumes	2,4,0			3,4,0	
Oliviers entretenus	2,4,1			3,4,1	
Autres vergers (figuiers, noyers...) y.c. jeunes plantations	2,4,2			3,4,2	
Petits fruits (framboises, cassis, etc.)	2,4,3			3,4,3	
Pépinières ligneuses	2,4,4			3,4,4	
Autres (préciser)	2,4,5			3,4,5	
TOTAL	2,4,9			3,4,9	
SUPERFICIE TOUJOURS EN HERBE (STH)					
Prairies permanentes	2,5,0			3,5,0	
Parcours et landes productifs	2,5,1			3,5,1	
TOTAL	2,5,9			3,5,9	
JARDIN FAMILIAL	2,6,9			3,6,9	
SUPERFICIE AGRICOLE UTILISÉE	2,7,9			3,7,9	
Sols des bâtiments et cours	2,8,0				
Landes et friches non productives	2,8,1				
SUPERFICIE AGRICOLE UTILE	2,8,9				
Peupleraies	2,9,0				
Bois et forêts	2,9,1				
Territoire non agricole	2,9,2				
SUPERFICIE TOTALE	2,9,9				

OBSERVATIONS :

ANNEX 4-E U.S.D.A.

Farm Report, Acreage and Production of Grain Crops

Crop Reporting Board
Statistical Reporting Service
U.S. Department of Agriculture

FARM REPORT

Ind. III.

Please make corrections in name, address, and ZIP Code, if necessary.

PLEASE MAIL BY JUNE 1, 1977

Dear Crop Reporter,

With most crops up, more interest is shown in the summary of crop conditions. This service is possible only with help of volunteer reporters like you. Thanks.

Let us have any additional comments you want to make on this month's weather. . . .or other factors affecting the condition of crops.

Please remember to:

1. Note the instructions.

2. Mail your report promptly in the enclosed envelope which needs no stamp.

Respectfully,

Bruce M. Graham
Chairman, Crop Reporting Board

P.S. Individual reports are kept confidential.

"Farm With Facts"

INSTRUCTIONS

Report the condition of crops and pastures now, as compared with the normal growth and vitality you would expect at this time, if there had been no damage from unfavorable weather, insects, pests, etc. Let 100 percent represent a normal condition for field crops or a full crop for fruits.

- Use letter F to indicate an entire failure. Enter dash (–) for the questions that do not apply to your locality. On questions relating to your operations, enter 0 when zero or none is the answer.
- In reporting grain sold and to be sold, include quantities of the 1976 crop only. Report sales to date plus expected future sales from the 1976 crop. Include the landlord's share as sales if it is moved off this place. Also, include 1976 grains placed under loan or purchase agreement as sales except quantities you expect to redeem and feed.

Please Answer These Questions For All Land You Operate	Answer here
CROP PRODUCTION AND STOCKS	
Report total old-crop stocks on this farm regardless of ownership or intended use. Include all whole (not ground) grain on this farm intended for feeding, for sale, and for seed as well as quantities under loan or reseal programs. Exclude new-crop (1977) grain and all grain you own that is stored off the farm you operate.	
CORN produced on this farm last year (1976 crop) – 70 lb. ear or 56 lb. shelled **BUSHELS**	011
CORN on this farm June 1, 1977 from 1976 and earlier years – 70 lb. ear or 56 lb. shelled **BUSHELS**	012
WHEAT produced on this farm last year (1976 crop) – 60 pound **BUSHELS**	031
WHEAT, old crop, on this farm June 1, 1977 from 1976 and earlier years – 60 pound **BUSHELS**	032
OATS produced on this farm last year (1976 crop) – 32 pound **BUSHELS**	091
OATS on this farm June 1, 1977 from 1976 and earlier years – 32 pound **BUSHELS**	092
BARLEY produced on this farm last year (1976 crop) – 48 pound **BUSHELS**	101
BARLEY, old crop, on this farm June 1, 1977 from 1976 and earlier years – 48 pound **BUSHELS**	102
RYE produced on this farm last year (1976 crop) – 56 pound **BUSHELS**	131
RYE, old crop, on this farm June 1, 1977 from 1976 and earlier years – 56 pound **BUSHELS**	132
SOYBEANS produced on this farm last year (1976 crop) – 60 pound **BUSHELS**	141
SOYBEANS on this farm June 1, 1977 from 1976 and earlier years – 60 pound **BUSHELS**	142
SORGHUM GRAIN produced on this farm last year (1976 crop) – 56 pound **BUSHELS**	161
SORGHUM GRAIN on this farm June 1, 1977 from 1976 and earlier years – 56 pound **BUSHELS**	162
CROP SALES	
CORN of 1976 crop sold and to be sold – 70 lb. ear or 56 lb. shelled **BUSHELS**	013
OATS of 1976 crop sold and to be sold – 32 pound **BUSHELS**	093
BARLEY of 1976 crop sold and to be sold – 48 pound **BUSHELS**	103
SORGHUM GRAIN of 1976 crop sold and to be sold – 56 pound **BUSHELS**	163
Please Answer These Questions For Your Locality	**Answer here**
FIELD CROPS	
WHEAT, condition of crop to be harvested for grain – **PERCENT**	030
WHEAT, probable yield per acre this year in 60-pound **BUSHELS**	039
PASTURE condition in **PERCENT**	266
ALL CROP PROSPECTS for 1977, as percent of normal – **PERCENT**	470
FRUIT CROP	
PEACHES, condition as a percent of a full crop – **PERCENT**	575

Figure 7.6 State Farm Report Survey--Indiana.

Crop Reporting Board
Statistical Reporting Service
U.S. Department of Agriculture

INDIANA CROP REPORTING SERVICE
Agricultural Administration Building
Purdue University
West Lafayette, Indiana 47907

Form Approved
O. M. B. Number 40-R0127
Approval Expires 7-31-77
C.E. 82-9826E

ACREAGE AND PRODUCTION OF GRAIN CROPS – 1976

Dear Reporter:

The information requested on this inquiry is needed for preparing final estimates of acreage and yield of small grain crops this year. Please fill in the information as completely and accurately as possible, and return this inquiry in the enclosed envelope which needs no stamp. Your report will be kept confidential.

Sincerely,

Earl L. Park
Agricultural Statistician in Charge

Please make corrections in name, address and Zip Code, if necessary.

INSTRUCTIONS: Please report for each crop listed below the planted acreage and use made of the planted acreage. In reporting acres harvested and production, include acres that still remain to be harvested and probable production.

REPORT FOR ALL LAND YOU OPERATE		Answer here
1. Wheat planted for all purposes last fall and this spring	Acres	680
2. Wheat harvested for grain	Acres	685
	Bushels	690
3. Wheat used for hay, silage, pasture only, plowed under or abandoned	Acres	710
4. Oats planted for all purposes last fall and this spring	Acres	385
5. Oats harvested for grain	Acres	388
	Bushels	391
6. Oats used for hay, silage, pasture only, plowed under or abandoned	Acres	403
7. Barley planted for all purposes last fall and this spring	Acres	001
8. Barley harvested for grain	Acres	006
	Bushels	011
9. Barley used for hay, silage, pasture only, plowed under or abandoned	Acres	031
10. Rye planted for all purposes last fall and this spring	Acres	470
11. Rye harvested for grain	Acres	473
	Bushels	476
12. Rye used for hay, silage, pasture only, plowed under or abandoned	Acres	488
13a. ALL OTHER CROPS not reported above	Acres	905
13b. Of the above acres of small grains harvested for grain (Items 1 through 12) on how many acres were soybeans planted as a second crop	Acres	624
14. ACRES OF ALL LAND in the farm you are operating (*Include land rented from others, but exclude land rented out*)	Acres	595

Please check here ☐ if you would like to receive a report of the results of this survey ..... OFFICE USE 998

Reported by _____ Date _____

Figure 7.2 Mail survey form for obtaining data on acreage and production of grain crops (SRS, USDA).

ANNEX 5

SOME METHODS FOR CALCULATION OF AREAS OF POLYGONS SUITABLE FOR POCKET AND DESK PROGRAMMABLE CALCULATORS [1]

Introduction

This article deals with the well-known traditional method of measurement of areas in agricultural statistics, which consists of identifying the boundaries of a field to be measured by use of sight poles and taking compass bearings and measuring the length of each side of a so obtained polygon. The traditional procedure of evaluating the area of a field on the basis of measurements consisted in plotting the field in the office by use of a planchette or a ruler and a protractor and then measuring the area of the sketch by use of a planimetre or grid paper.

This traditional procedure of evaluating the area can successfully be replaced by use of the programmable pocket or desk calculators which appeared on the market in the early 1970ties. The Statistics Division of FAO has developed several methods of calculating areas which are suitable for programmable calculators. These methods were first implemented in the 1974 Census of Agriculture in Ivory Coast.

These procedures are presented and evaluated in the latter part of this article.

The advantages of calculators over the traditional method of calculation of areas are multifold. They consist not only in simplicity of use and speed (it takes about 1 to 4 minutes to calculate the area of a field depending on the number of sides) but also in the fact that possible errors in the classical method, such as errors in plotting the sketch, errors in measuring the area from the sketch and, in particular, errors in applying the scale factor, are eliminated. Use of the calculators also permits the application of methods of distributing the closure error to all vertices, which is superior to the hand method of handling the closure error. Perhaps the most important advantage of the calculator is the possibility to use it directly in the field when measurements are made, as the closure error can be evaluated directly on the spot and in case of too large an error the measurements can be repeated.

Calculation of the area of a polygon

Let a polygon with n sides be defined by

$$a_i, \alpha_i \qquad i = 1, 2, \ldots, n$$

where a_i is the length of the side i and α_i is the angle this side forms with North measured in clockwise direction.

Denote with $\vec{a_i}$ the vector which represents the side i in a two dimensional space XOY in which Y-axis coincides with the North.

The horizontal and vertical projections of the vector $\vec{a_i}$ (see Figure 1) are respectively:

$$a_i \operatorname{Sin} \alpha_i$$

$$a_i \operatorname{Cos} \alpha_i$$

1/ Prepared by P.I. Petricevic, Statistician, Statistics Division, FAO.

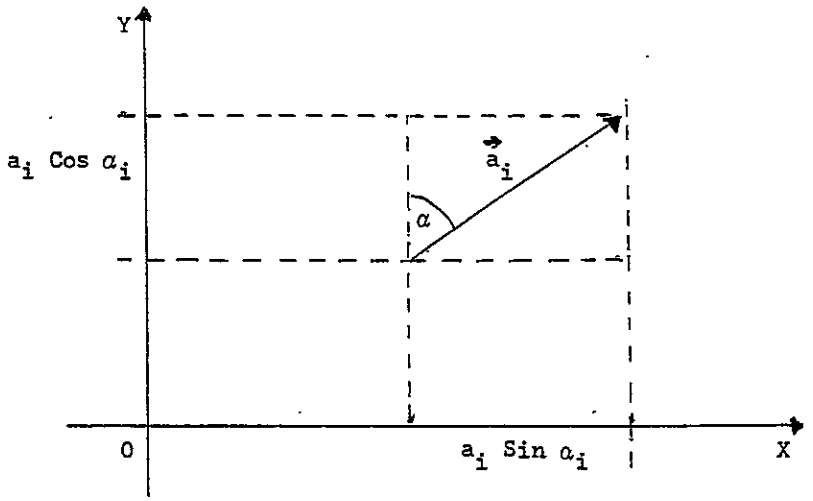


Figure 1

Define vectors

$$\vec{R}_i = \sum_{j=1}^{i} a_j \qquad i = 1, 2, \ldots, n \tag{1}$$

Their horizontal and vertical projections will be respectively:

$$X_i = \sum_{j=1}^{i} a_j \text{ Sin } \alpha_j \tag{2}$$

$$Y_i = \sum_{j=1}^{i} a_j \text{ Cos } \alpha_j \tag{3}$$

If the polygon is closed, then

$$\vec{R}_n = 0 ,$$

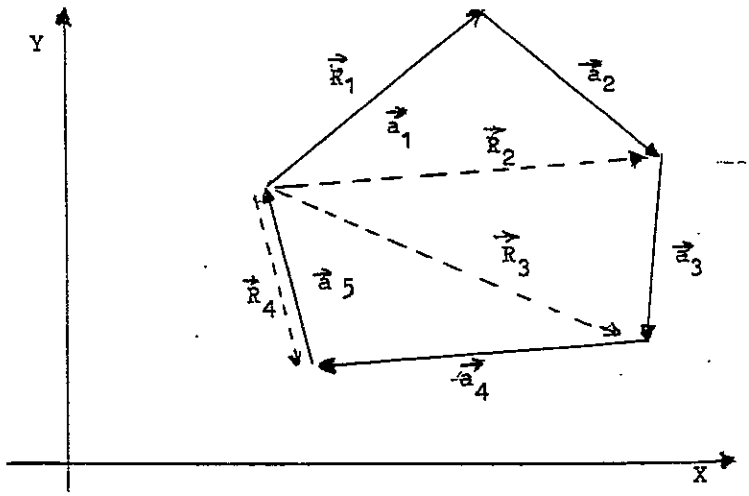


Figure 2

The area of a triangle formed by two vectors which start from the same point can be calculated as a function of their horizontal and vertical projections.

Thus the area of the triangle between vectors $\vec{R}_1$ and $\vec{R}_2$ (see Figure 2) is given by:

$$A_1 = \frac{1}{2}(X_2Y_1 - X_1Y_2)$$

It should be noted that this area will have a positive value if the vector $\vec{R}_1$ precedes the vector $\vec{R}_2$ (looking clockwise), otherwise it will be negative.

The area of the whole polygon calculated as a sum of areas of triangles, each formed by the two consecutive vectors $\vec{R}_i$, will be:

$$A = \frac{1}{2}\sum_{i=1}^{n-2}(X_{i+1}Y_i - X_iY_{i+1}) \qquad (4)$$

where X_i and Y_i are given by (2) and (3).

Closure error and corrected area of a polygon

In practice the polygon defined by the data which are collected in the field will never close. In this case

$$\vec{R}_n \neq 0.$$

The length of the vector $\vec{R}_n$

$$R_n = \sqrt{X_n^2 + Y_n^2}$$

can be used as a measure of error. The normal practice is, however, to express the closure error as percent of the perimeter of the polygon:

$$C = \frac{R_n}{\sum_{i=1}^{n} a} \times 100$$

If the closure error is below a certain value, say 2%, the error may be considered as acceptable. The polygon can be closed in different ways and the area of a so closed polygon calculated. Let us consider different methods of closing the polygon.

A. Closure by connecting the last but one point with the starting point

This is the simplest method of closing the polygon (see Figure 3) in which the measurements taken for the last side of the polygon are not taken into account for the calculation of area. The formula to be applied in this case is given in (4). It should be noted that, if this method is applied, the measurements for the last side still have to be taken in order to permit the evaluation of the closure error.

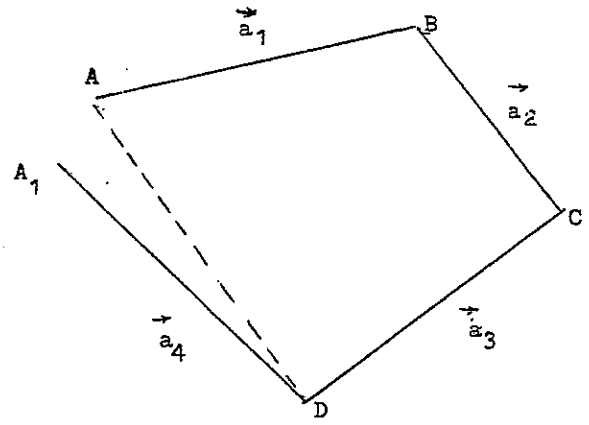


Figure 3

B. Closure from the mid-point

The method will be illustrated by use of Figure 4.

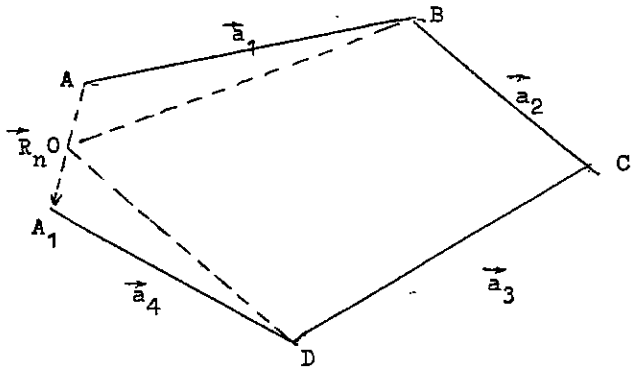


Figure 4

The closed polygon OBCDO is obtained by connecting the mid-point O between end points A and A_1 with the ends of the first and the last side of the open polygon, that is with points B and D.

Define new vectors $\vec{R}_i'$:

$$\vec{R}_i' = \vec{R}_i - \frac{1}{2}\vec{R}_n \qquad i = 1, 2, \ldots, n-1$$

with projections

$$X_i' = X_i - \frac{1}{2} X_n \tag{5}$$

$$Y_i' = Y_i - \frac{1}{2} Y_n \tag{6}$$

Then the area of the closed polygon will be

$$A = \frac{1}{2} \sum_{i=1}^{n-2} (X'_{i+1} Y'_i - X'_i Y'_{i+1})$$

or after substituting X'_i and Y'_i from (5) and (6)

$$A = \frac{1}{2} \sum_{i=1}^{n-2} (X_{i+1} Y_i - X_i Y_{i+1}) + \frac{Y_n}{4} (X_1 - X_{n-1}) - \frac{X_n}{4} (Y_1 - Y_{n-1}) \qquad (7)$$

where X_i and Y_i are defined by (2) and (3).

C. Closure by shifting all vertices on equal basis

This method is illustrated by Figure 5, which shows an open polygon $ABCDA_1$. Straight lines parallel to the AA_1 are drawn through each of the vertices. The vertices are shifted along these lines so that the first one is shifted by

$\frac{1}{n} \overline{AA_1}$, second by $\frac{2}{n} \overline{AA_1}$, and so on.

$$\overline{B^1B} = \frac{1}{4} \overline{AA_1}$$

$$\overline{C^1C} = \frac{2}{4} \overline{AA_1}$$

$$\overline{D^1D} = \frac{3}{4} \overline{AA_1}$$

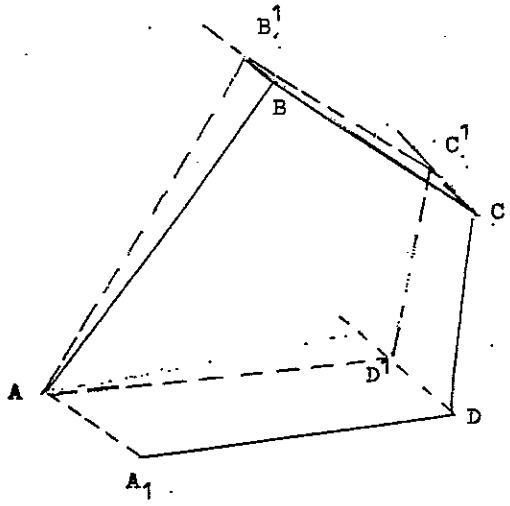


Figure 5

In this way a closed polygon $AB^1C^1D^1A$ is obtained.

New vectors $\overrightarrow{R'_i}$ are defined by:

$$\overrightarrow{R'_i} = \overrightarrow{R_i} - \frac{i}{n} \overrightarrow{R_n} \qquad i = 1, 2, \ldots, n-1$$

with projections

$$X'_i = X_i - \frac{i}{n} X_n \qquad (8)$$

$$Y'_i = Y_i - \frac{i}{n} Y_n \qquad (9)$$

The area of the closed polygon will be:

$$A' = \frac{1}{2} \sum_{i=1}^{n-2} (X'_{i+1} Y'_i - X'_i Y'_{i+1})$$

or after substituting (8) and (9), and reordering and simplifying the expression obtained:

$$A' = \frac{1}{2} \sum_{i=1}^{n-2} (X_{i+1} Y_i - X_i Y_{i+1}) - Y_n \left(\frac{X_{n-1}}{2} - \frac{\sum_{i=1}^{n-1} X_i}{n}\right) + X_n \left(\frac{Y_{n-1}}{2} - \frac{\sum_{i=1}^{n-1} Y_i}{n}\right) \qquad (10)$$

where X_i and Y_i are defined by (2) and (3).

Formula (10) can be further reorganized to take a form more suitable for computer programming:

$$A' = \frac{1}{2} \sum_{i=1}^{n} (Y_i \Delta X_i - X_i \Delta Y_i) + \frac{Y_n}{n} \sum_{i=1}^{n} X_i - \frac{X_n}{n} \sum_{i=1}^{n} Y_i \qquad (11)$$

where

$$\Delta X_i = a_i \operatorname{Sin} \alpha_i$$

$$\Delta Y_i = a_i \operatorname{Cos} \alpha_i$$

and

$$X_i = \sum_{j=1}^{i} \Delta X_j$$

$$Y_i = \sum_{j=1}^{i} \Delta Y_j$$

D. <u>Closure by shifting all vertices on proportionate basis</u>

This procedure is similar to the preceding one. While in the preceding procedure the closure error was equally distributed to all vertices, it is now distributed proportionately to the length of sides.

The new vector $\overrightarrow{R_i}$ is defined by:

$$\overrightarrow{R_i} = \overrightarrow{R_i} - \frac{\sum_{j=1}^{i} a_j}{\sum_{j=1}^{n} a_j} \overrightarrow{R_n}$$

with projections

$$X_i' = X_i - \frac{\sum_{j=1}^{i} a_j}{\sum_{j=1}^{n} a_j} X_n \qquad (12)$$

$$Y_i' = Y_i - \frac{\sum_{j=1}^{i} a_j}{\sum_{j=1}^{n} a_j} Y_n \qquad (13)$$

The corrected area can be calculated by substituting the values calculated from (12) and (13) into (4). In this case a simple general formula cannot be obtained.

Comparison of methods

The four methods of dealing with the closure error have different characteristics from the computational point of view. It should be noted that in the case of the first three methods (A. Closure by connecting the last but one point with the starting point; B. Closure from the mid-point; and C. Closure by shifting all vertices on equal basis) there is no need to keep in the memory all input data till the end of calculation. In these three methods each pair of input data can be elaborated when they are entered, and required sums can be aggregated. As soon as the last pair of data is entered, corrected area and closure error can be evaluated. In the case of the fourth method (D. Closure by shifting all vertices on proportionate basis) it is necessary to keep in the memory all input data for one polygon till the end of calculation. This means that the first three methods can be programmed even for small programmable calculators as they do not require more than 8 registers for storage of data and intermediate results, irrespective of the number of sides of the polygon. The fourth method required two registers for each vertix and several more for intermediate results.

It can be shown that each of the four methods gives an unbiased estimate of the true area, provided, of course, that there is no bias in the measurements.

There are two important questions which cannot be answered analytically:

1. Given the closure error, what will be the expected error in area estimates?
2. Is there any significant difference in precision of area estimates as obtained by different methods of dealing with the closure error?

In an attempt to shed some light on the above questions a simulation model was applied. For this purpose a "typical polygon" with seven sides which closed "perfectly" was chosen. The compass bearings and the length of sides of the polygon are given below:

Side	Angle (degrees)	Length (metres)
AB	22.62	130
BC	102.68	205
CD	180	110
DE	225	35.3555
EF	306.87	50
FG	253.74	125
GA	315	91.924

Area = 3.33 ha. Closure error = 0.0002 percent.

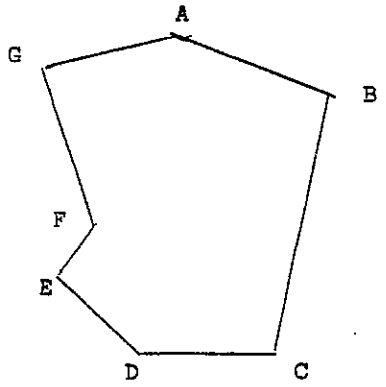


Figure 6

In the above data random errors were introduced. Four different types of errors were considered independently. Two types of errors were introduced in the length of sides, one independent of the length of sides and another proportionate to the length of sides. Two types of errors were also introduced in angles, one independent of the length of side and another inversely proportionate to the length of side - the last type of error occurs if the sight poles indicating end points of the side are not perfectly parallel.

Random errors were drawn from the normal distribution with zero mean. For each side and each angle a new random error was drawn. The standard deviations of the errors of different types were given the values which resulted in an average closure error of 1 percent. With these assumptions 1 000 simulations were made for each of the four types of errors, and each time the four different area estimates were calculated. The results are summarized in the table below:

Percentage standard errors of different area estimates corresponding to the expected closure error of 1 percent

Kind of random error		Percentage standard eror of area estimate			
		Method A	Method B	Method C	Method D
Error in length of sides	S.D. constant	3.1	3.2	2.3	2.4
	S.D. proportionate to the length of side	3.3	2.9	2.4	2.3
Error in angles	S.D. constant	2.3	2.2	1.1	1.1
	S.D. inversely proportionate to the length of side	2.0	2.0	0.7	0.6

From the above table only indicative conclusions can be made, not only because the number of simulations was not large enough, but also because a similar exercise with a different polygon would produce different results.

Nevertheless, the following remarks are possible. Method A produces similar results as Method B and also Method C is similar to Method D. Methods C and D give much better estimates of area than methods A and B, particularly if the measurement errors occur in angles rather than in lengths. In this case application of superior methods reduces the error to half or less.

In other words, one can recommend the use of calculators which permit the application of Method C. Calculators with larger memory which can be programmed for Method D do not seem to be worth the cost for this application. For simpler programmable calculators which cannot deal with Method C, Method A is good enough.

Experience with pocket programmable calculators

The programme for calculation of areas by use of Method C was written for the following pocket calculators:

Hewlett Packard	- HP-25/25C HP-29C HP-55 HP-65 HP-67
Texas Instruments	- SR-52 SR-56 T1-58/59 and T1-58C/59C
Casio	- fx-201P fx-501P/502P

All programmable calculators with trigonometric functions and having at least 8 registers and 100 programming steps, can be used for calculation of areas. Some calculators need even less steps (HP-25 only 49 steps) depending on the efficiency of the programming language.

Of the calculators tested, the more suitable for calculation of areas, particularly for field application, are those which have programmes stored on magnetic cards. These are HP-67, HP-65, SR-52 and T1-59/59C. Almost equally suitable are calculators with permanent memory since in these calculators the programme, once keyed in, remains in the memory even after the calculator is switched off. Such calculators are HP-25C, HP-29C, T1-58C and Casio fx-501P/502/P.

The other calculators require that the programme be keyed in manually each time the calculator is switched on. This operation takes less than five minutes, but requires better knowledge of the calculator. Still, these calculators can be recommended for office use.

The programmes for HP-25/25C, HP-29C, T1-58/59 and T1-58C/59C, and Casio fx-501P/502P are appended to this chapter. The programmes for other calculators, including new ones for which programmes are being prepared when they appear on the market, can be obtained on request from Statistics Division, FAO, Rome.

SELECTED PROGRAMMES FOR POCKET CALCULATORS

Formulae applied

These programmes calculate the area of polygon of n sides, defined by:

$$\alpha_j,\ a_j \qquad j = 1, 2, \ldots, n$$

where α_j is the angle (in degrees) the side j forms with North measured in clockwise direction, and a_j is the length of this side.

Let $$\Delta X_j = a_j \text{ Sin } \alpha_j$$

$$\Delta Y_j = a_j \text{ Cos } \alpha_j ,$$

and let $$X_i = \sum_{j=1}^{i} \Delta X_j$$

$$Y_i = \sum_{j=1}^{i} \Delta Y_j$$

The area of the polygon (A), and the closure error (distance between the starting and ending point) expressed as percent of the perimeter (C), will respectively be:

$$A = \frac{1}{2} \sum_{i=1}^{n} (Y_i \Delta X_i - X_i \Delta Y_i) + \frac{Y_n}{n} \sum_{i=1}^{n} X_i - \frac{X_n}{n} \sum_{i=1}^{n} Y_i$$

$$C = 100 \times \sqrt{X_n^2 + Y_n^2} \Big/ \sum_{i=1}^{n} a_i$$

The area calculated represents the area of a closed polygon obtained by shifting the vertices of the given polygon along the lines parallel to the line passing through the starting and ending point. The vertex i is shifted by the i/n fraction of the distance between starting and ending point.

Programme for HP-25/25C

Display Line	Display Code	Key entry
00	////////////////////	
01	14 34	f STK
02	14 33	f REG
03	24 03	RCL 3
04	74	R/S
05	23 51 00	ST + 0
06	14 09	f → R
07	25	Σ +
08	22	R↓
09	21	x ⇄ y
10	22	R↓
11	14 73	f LASTx
12	24 04	RCL 4
13	23 51 02	STO + 2
14	61	X
15	21	x ⇄ y
16	24 07	RCL 7
17	23 51 01	STO + 1
18	61	X
19	41	-
20	41	-
21	13 03	GTO 03
22	34	CLx
23	02	2
24	71	÷

Display Line	Display Code	Key entry
25	14 21	f $\bar{x}$
26	24 02	RCL 2
27	61	X
28	24 04	RCL 4
29	24 03	RCL 3
30	71	÷
31	24 01	RCL 1
32	61	X
33	41	-
34	51	+
35	01	1
36	00	0
37	00	0
38	00	0
39	00	0
40	71	÷
41	74	R/S
42	24 04	RCL 4
43	24 07	RCL 7
44	15 09	g → P
45	24 00	RCL 0
46	71	÷
47	33	EEX
48	02	2
49	61	X

Registers	
R_o	Σa_i
R_1	ΣX_i
R_2	ΣY_i
R_3	n
R_4	Y_i
R_5	USED
R_6	USED
R_7	X_i

REMARK: This programme is made to calculate area in hectares for input in metres. Should different units be used, the conversion factor 10 000 given in lines 35-39 should be changed:

Input	Output	Conversion factor
Metres	Sq.metres	1.000
Feet	Acres	43 560
Feet	Sq.feet	1.000

Example:

j (side)	α_j (angle : degrees)	a_j (length : metres)
1	15	430
2	64	360
3	168	420
4	253	540

A = 17.16 ha. C = 0.42%.

Instructions

Step	Instruction	Input	Keys	Output
1	Enter programme			
2	Initialize		GTO 0 0 R/S	0.00
3	Perform 3 for j = 1, 2, ..., n	α_j a_j	↑ R/S	j
4	Calculate area		GTO 2 2 R/S	A
5	Calculate closure error		R/S	C
6	For a new case go to 2			

Programme for HP-29C

Display Line	Display Code	Key entry
00	////////	//////////
01	15 13 01	gLBL1
02	34	CLx
03	31	ENTER↑
04	31	ENTER↑
05	14 33	fREG
06	15 13 04	gLBL4
07	24 .0	RCL.0
08	74	R/S
09	23 51 03	STO÷3
10	14 44	f→R
11	25	Σ+
12	22	R↓
13	21	x⇄y
14	22	R↓
15	14 73	fLASTx
16	24 .3	RCL.3
17	23 51 02	STO÷2
18	61	X
19	21	x⇄y
20	24 .1	RCL.1
21	23 51 01	STO÷1
22	61	X
23	41	-
24	41	-
25	13 04	GTO4
26	15 13 02	gLBL2
27	34	CLx
28	02	2

Display Line	Display Code	Key entry
29	71	÷
30	24 .1	RCL.1
31	24 02	RCL2
32	61	X
33	24 .3	RCL.3
34	24 01	RCL1
35	61	X
36	41	-
37	24 .0	RCL.0
38	71	÷
39	51	+
40	01	1
41	00	0
42	00	0
43	00	0
44	00	0
45	71	÷
46	74	R/S
47	15 13 03	gLBL3
48	24 .3	RCL.3
49	24 .1	RCL.1
50	15 44	g→P
51	24 03	RCL3
52	71	÷
53	33	EEX
54	02	2
55	61	X
56	74	R/S

Registers	
R_1	ΣX_i
R_2	ΣY_i
R_3	Σa_i
$R_{.0}$	i
$R_{.1}$	X_i
$R_{.2}$	USED
$R_{.3}$	Y_i
$R_{.4}$	USED
$R_{.5}$	USED

REMARK: This programme is made to calculate area in hectares for input in metres. Should different units be used, the conversion factor 10000 given in lines 40–44 should be changed.

Input	Output	Conversion factor
Metres	Sq.metres	1.000
Feet	Acres	43560
Feet	Sq.feet	1.000

Example:

j (side)	α_j (angle : degrees)	a_j (length : metres)
1	15	430
2	64	360
3	168	420
4	253	540

A = 17.16 ha. C = 0.42%

Instructions

Step	Instruction	Input	Keys	Output
1	Instruction			
2	Initialize		GSB 1	0.00
3	Perform 3 for	α_j	ENT↑	
	j = 1, 2, ..., n	a_j	R/S	j
4	Calculate area		GSB 2	A
5	Calculate closure error		GSB 3	C
6	For a new case go to 2			

Programme for TI-58/59 and TI-58C/59C

DISPLAY LINE	CODE	KEY
000	76	*Lbl
001	15	E
002	47	*CMs
003	58	*Fix
004	02	2
005	25	CLR
006	91	R/S
007	44	SUM
008	02	2
009	32	x⇄t
010	37	*P→R
011	44	SUM
012	03	3
013	32	x⇄t
014	44	SUM
015	04	4
016	65	X
017	43	RCL
018	03	3
019	44	SUM
020	05	5
021	95	=
022	94	+/-
023	44	SUM
024	07	7
025	32	x⇄t
026	65	X

DISPLAY LINE	CODE	KEY
027	43	RCL
028	04	4
029	44	SUM
030	06	6
031	95	=
032	44	SUM
033	07	07
034	01	1
035	44	SUM
036	01	1
037	43	RCL
038	01	1
039	61	GTO
040	00	0
041	06	06
042	76	*Lbl
043	11	A
044	43	RCL
045	07	7
046	55	÷
047	02	2
048	95	=
049	85	+
050	53	(
051	43	RCL
052	04	4
053	65	X

DISPLAY LINE	CODE	KEY
054	43	RCL
055	05	5
056	75	-
057	43	RCL
058	03	3
059	65	X
060	43	RCL
061	06	6
062	54	)
063	55	÷
064	43	RCL
065	01	1
066	95	=
067	55	÷
068	01	1
069	00	0
070	00	0
071	00	0
072	00	0
073	95	=
074	91	R/S
075	76	*Lbl
076	13	C
077	43	RCL
078	03	3
079	32	x⇄t
080	43	RCL

DISPLAY LINE	CODE	KEY
081	04	4
082	22	INV
083	37	*P→R
084	32	x⇄t
085	65	X
086	01	1
087	00	0
088	00	0
089	55	÷
090	43	RCL
091	02	2
092	95	=
093	91	R/S

REGISTERS	
R_1	i
R_2	Σa_i
R_3	x_i
R_4	y_i
R_5	Σx_i
R_6	Σy_i
R_7	USED
R_8	USED
R_9	USED

* Indicates 2nd function key.

NOTE: This programme is made to calculate area in hectares for input in meters. Should different units be used, the conversion factor 10 000 given in lines 68-72 should be changed as follows:

Input	Output	Conversion factor
Feet	Sq. feet	1.000
Metres	Sq. metres	1.000
Feet	Acres	43 560

Example:

j (side)	α_j (angle : degrees)	a_j (length : meters
1	15	430
2	64	360
3	168	420
4	253	540

A = 17.16 ha. C = 0.42%

Instructions:

Step	Instruction	Input	Keys	Output
1	Enter programme		2nd CP LRN enter programme LRN	
2	Initialize		E	0.00
3	Perform 3 for j = 1, 2, ..., n	α_j a_j	x⇄t R/S	j
4	Calculate area		A	A
5	Calculate closure error		C	C
6	For a new case go to 2			

Programme for CASIO FX-501P/502P

PROGRAMME (Do not key in commas ",")

P0 Min 0, HLT, x_D, INV P→R, MR 0, =, M+ 1, Min 6, INV X↔Y, M+ 3, X, MR 1, =, M+ 5, MR 6, X, MR 3, =, M− 5, MR 1, M+ 2, MR 3, M+ 4, GSB P3, (24 instructions)

P1 MR 1, INV R→P, MR 3, =, ÷, MR 8, X, 1, 0, 0, =, GSB INV P5, HLT, (13 instructions)

P2 MR 4, X, MR 1, −, MR 2, X, MR 3, =, ÷, MR 9, +, MR 5, ÷, 2, =, ÷, 4, INV 10^x, GSB INV P5, HLT, (20 instructions)

P3 MR 9, (1 instruction)

P4 INV MAC, GSB P3, (2 instructions)

INV P5 ÷, INV ABS, Min 6, X, ∫(, 2, INV 10^x, X, X↔M 6, +, ', 5,)∫, INV INT, ÷, MR 6, =, (17 instructions)

Instructions for entering the programme

1. Press: MODE 3
2. Press: INV MAC (cancels all programmes)
   In case one subroutine, for example P0, has to be cancelled, press P0, AC
3. Press: MODE 2 (programme writing)
4. Enter all programme
5. Press: MODE 1
6. Test programme with given example

Rounding to 2 decimals of A and C is performed by INV P5.
Should different number of decimals be required, the factor 2 (sixth instruction in INV P5) should be changed accordingly.

Example:

j (side)	α_j (angle : degrees)	a_j (length : metres)
1	15	430
2	64	360
3	168	420
4	253	540

A = 17.16 ha C = 0.42%

Instructions for running the programme:

Step	Instruction	Input	Keys	Output
1	Initialize		P4	0
2	Perform 2 for j = 1, 2, ..., n	α_j a_j	P0 EXE	α_j j
3	Calculate closure error		P1	C
4	Calculate area		P2	A
5	For a new case go to Step 1			