Page 2

– pest infestation in the field?	(1) ____	(2) ____	(3) ____	(4) ____
– yield?	(1) ____	(2) ____	(3) ____	(4) ____
– grain size?	(1) ____	(2) ____	(3) ____	(4) ____
– grain colour?	(1) ____	(2) ____	(3) ____	(4) ____
– storability?	(1) ____	(2) ____	(3) ____	(4) ____
– cooking time?	(1) ____	(2) ____	(3) ____	(4) ____
– taste?	(1) ____	(2) ____	(3) ____	(4) ____

(3) Is there any other important condition a variety should meet? ____

____

– what is the ranking with regard to this condition?

(1) ____ (2) ____ (3) ____ (4) ____

(4) What is the overall ranking of the varieties, considering all their advantages and disadvantages?

(1) ____ (2) ____ (3) ____ (4) ____

(5) Does the farmers intend to plant any of the tested varieties on his own farm in 1992?

Yes ☐ No ☐

a) if yes, which varietie(s)? ____

b) if yes, reason for his choice? if no, why not? ____

____

Chapter 6 Tools and methods for data analysis and presentation

Chapter 6 Tools and methods for data analysis and presentation

The raw material for the analysis of data comprises a multitude of information contained in questionnaires or record forms. This information must be organized and prepared for data processing, processed, and eventually compressed and represented in a form that can be used to draw reasonable conclusions with regard to the subject under examination.

Some kind of data analysis will be required for the exploration of demand for innovation as well as to identify available options and finally to assess tested options. The different nature of data collection methods was explained in Chapter 4. The non – formal or the formal character of the data collection will also determine the mode of data analysis.

6.1 Analysis of information from non-standardized data collection

The analysis of information from non-standardized data collection, for example information gained from dialogues on innovation or from exploratory surveys, is of descriptive nature. The analysis seeks to summarize a multitude of individual pieces of information and to deduce common tendencies and interrelationships. For example, it can produce:

- a description of farming systems, including farmers goals and preferences as well as background conditions and their influence on the development of farming systems;
- a description of the criteria an innovation must meet to satisfy farmers goals and preferences or to be compatible with environmental and socioeconomic conditions;
- an assessment, before or after experimentation, of the extent to which potential innovations coincide with farmers goals and preferences.

The analysis of information from non-standardized data collection will usually not yield quantitative and representative results. The results have therefore more the character of hypotheses. Verification through standardized data can be required if these hypotheses significantly influence the direction of a programme and the validity of a hypothesis is doubtful. Verification is advisable in any case in the final stage of research, in order to demonstrate the correspondence of an innovation with farmers' goals and preferences.

There are no standard routine procedures for the analysis of information from non-standardized data gathering. The following can only contain a collection of methods that have been successfully applied in the development of agricultural innovations. Every situation requires its own procedures. The examples are meant to stimulate the development of the readers' own methods, adapted to the specific project situation.

All methods described can be used right in the **dialogue with farmers** to help them structure their experiences and ideas.

The result of the analysis is not intended to be a comprehensive description of farming systems and their framework conditions. The aim is rather to highlight out key issues which are expected to have a bearing on the direction of the programme.

6.1.1 Cropping patterns

Diagrams, as they are shown in Figures 6.1 and 6.2 are a simple aid for visualizing the **distribution of crops in terms of space and time** in a readily understandable form.

Frequency distributions can be used to visualize **land use patterns**. Graphical aids often used are cross tabulations (see Table 6.1), pie charts (Figure 6.3) or bar charts (Figure 6.4).

Different reference frames are possible: land use patterns are often shown as an average for all farmers in a project or a specific geographical region. It will be helpful with regard to the programme design, however, if the land use pattern is related to **critical ecological** (e.g. soils, rainfall, etc.) **or socioeconomic parameters** (e.g. available land or labour etc.).

A **transect** through a defined zone (i.e. a geographical area, a watershed, a village or a farm) as shown in Figure 6.5 helps to relate simple information on land use pattern to critical factors of the respective microenvironment. This tool can be used by researchers in order to summarize information collected. It was moreover successfully applied in dialogues with farmers in order to discuss the ecological features of an area.

Figure 6.1: Diagram of the spatial arrangement of a three-crop mixture in northern Ghana (Steiner, 1984)

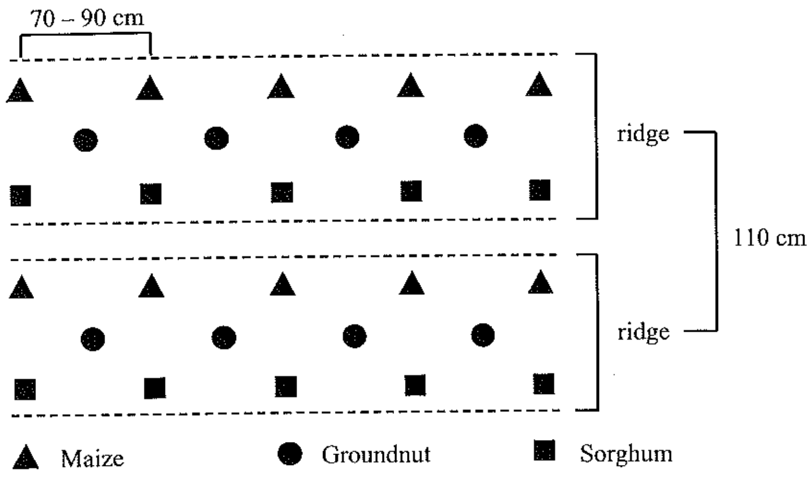
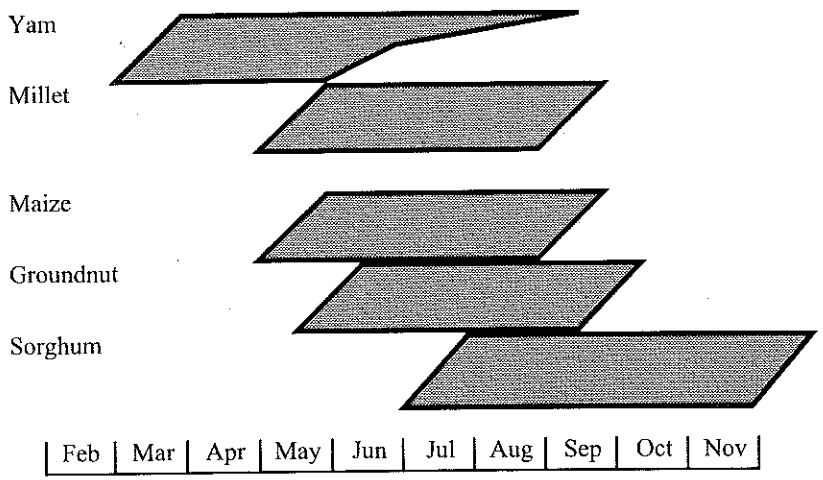


Figure 6.2: Diagram of principal cropping sequences identified during an exploratory survey in northern Ghana (adapted from Steiner, 1984)



Different tools can be used to analyze **historical developments**. The **bar chart** in Figure 6.4 shows the development of land use patterns. **Historical transects** are developed in the same way as geographical transects. The analysis of historical developments reveals already ongoing tendencies. These are often farmers responses to existing production constraints or changing circumstances. This kind of analysis can help to detect system constraints or to ask the right questions. Programme activities will be, furthermore, more promising if they have a direct bearing on already ongoing developments.

Table 6.1: Cross tabulation of land use pattern at Lake Kenyatta Settlement Scheme (Kenya) by dominant soil types, estimated % of cultivated area (adapted from Neunfinger, Schmale and Werner, 1987)

Type of cropping system	red loams (on coral reef)	sandy soils (Kilindini sand)
Tree crops pure stand	30	40
Annual crops pure stand	50	30
Tree crops + annual crops	20	30

Figure 6.3: Pie chart of land use patterns at Lake Kenyatta Settlement Scheme derived from tab. 6.1

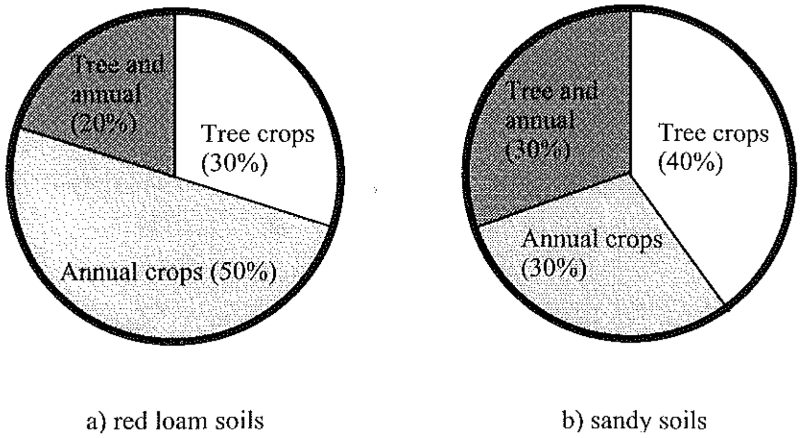


Figure 6.4: Bar chart (stacked bar) of past development of land use patterns at Lake Kenyatta Settlement Scheme

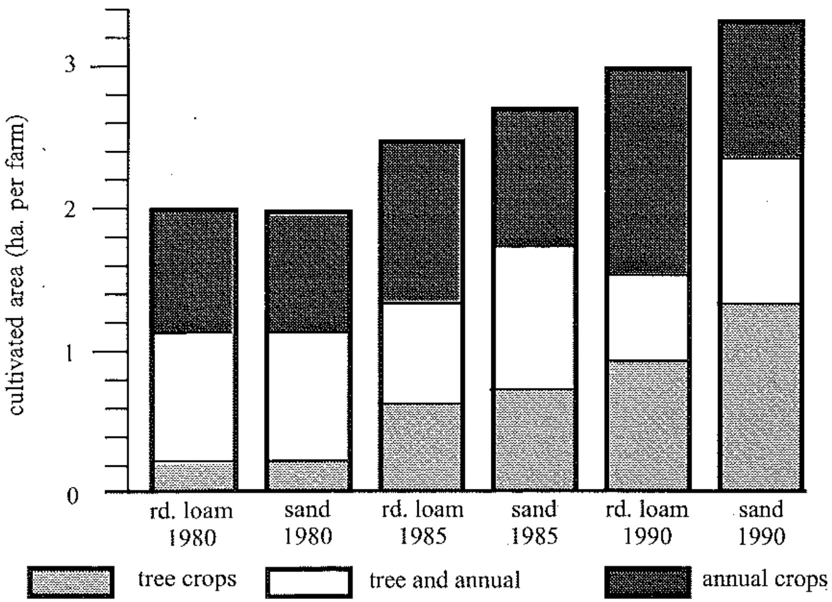
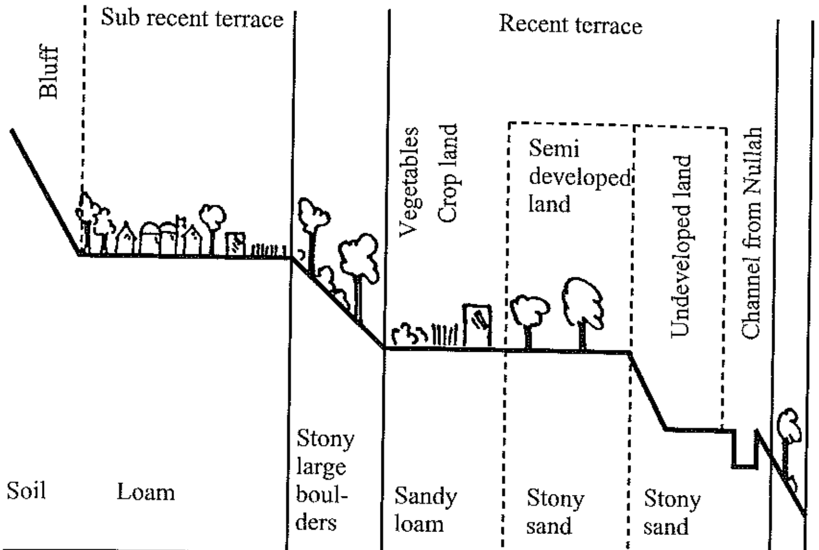


Figure 6.5: Transect of a village in northern Pakistan (Source: Conway, 1989)



Soil	Loam	Stony large boulders	Sandy loam	Stony sand	Stony sand	
Crops	Wheat-Maize, Mash Wheat-Fallow Vegetables Potatoes	Bushes trees	As for recent terrace	Willow Poplar Russian Olive Thorny Bushes	Scattered trees	
Livestock	Ruminants Free grazing in winter	Grazing	Free Grazing	Grazing		
Problems	Pod borer in mash Water flooding from can. Water shortages	Poor soil	Serious water shortages	Poor soil	Flooding	
Opportunities	Pest control Extend canals-irrigation and water control		Improve grazing, extend canals	More trees	Alfalfa irrigation	

6.1.2 Seasonal calendars

Seasonal calendars are diagrams which graphically present seasonal features. They are useful for the identification of system constraints. They help to assess the feasibility of potential innovations. Sometimes they also reveal times of the season which could be more efficiently used.

A calendar starting with a key event of the season (like the beginning of land preparation or the onset of the rainy season) is more appropriate than the conventional calendar beginning with January.

Most useful and common are representations showing the development of the following factors in the course of the seasons:

- climatic factors;
- cropping patterns;
- labour demand or availability for farm work;
- off farm employment opportunities;
- key events with regard to livestock production;
- prices for crops, livestock or food;
- availability of food, etc.

Figures 6.6 to 6.8 present some examples:

Figure 6.6 illustrates critical climatic features of an area in Malawi, in this case rainfall, which also includes the onset and end of the rainy season, and the probability of dry spells within the rainy season. Similar representations can be used to show the development of temperature, evaporation, etc in the course of the season. Information obtained from farmers can yield relatively reliable semi-quantitave estimates in the absence of measured data.

Figure 6.7 shows a labour allocation profile for selected crops from a project area in Kenya. The semi-quantitative representation reveals which crops compete for labour at which time of the year. If it is related to the land use pattern it helps to identify periods in which labour is highly demanded or labour slack periods. It helps to identify unused opportunities if it is considered in relation to critical climatic features and to price developments at the local market; etc.

Figure 6.8 synthesizes a number of critical seasonal features for a village in northern Pakistan.

Figure 6.6: Seasonal calendar of critical climatic data, (Liwonde ADD, Malawi)

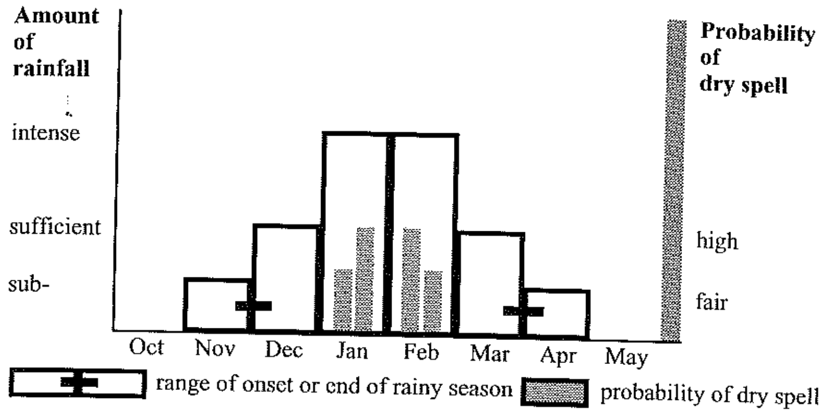


Figure 6.7: Labour allocation profile, Lake Kenyatta Settlement Scheme (Kenya), (adapted from Neunfinger, Schmale and Werner, 1987)

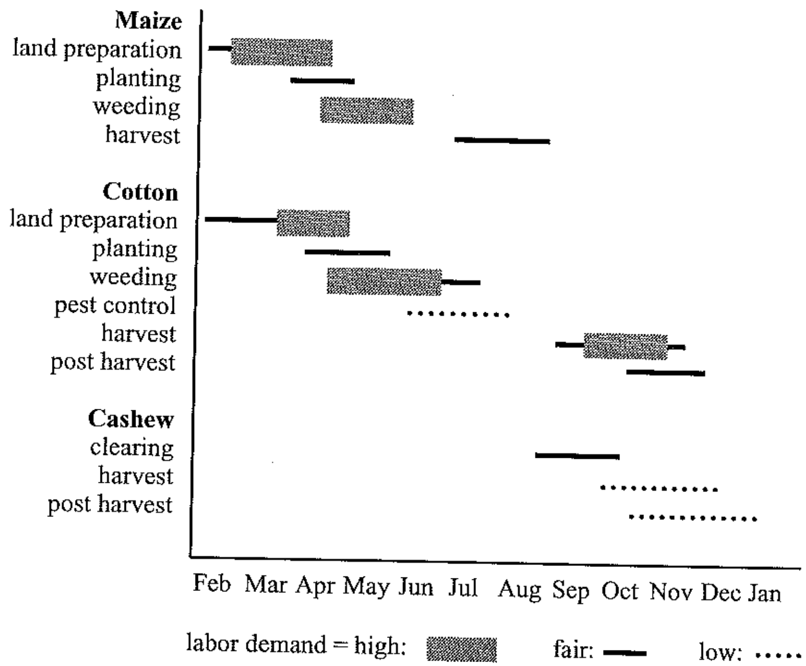
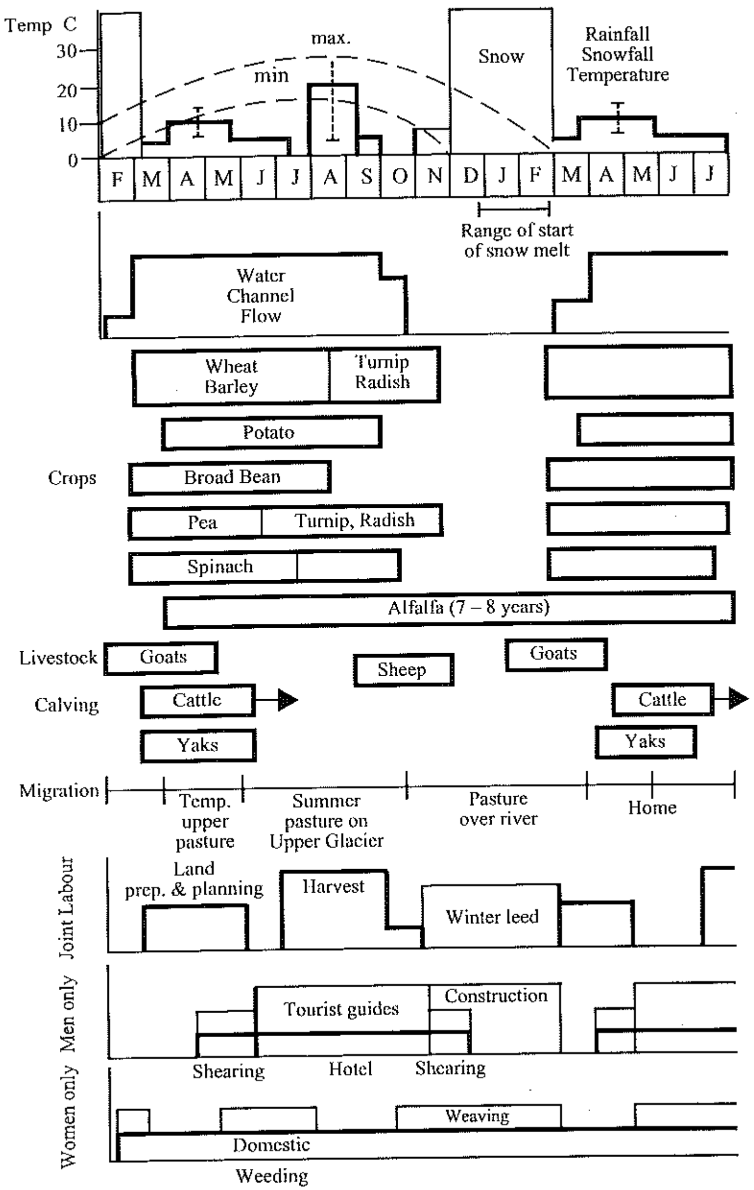


Figure 6.8: Seasonal calendar for a village in northern Pakistan (Conway, 1989)



6.1.3 Definition of "target groups"

Every farmer has his own particular goals and works under different circumstances from his neighbour. It is therefore hardly accurate to consider "farmers" as a homogeneous undifferentiated mass in programme planning and implementation.

Target grouping helps to strike a balance between two extreme alternatives: (a) to develop recommendations for each farmer (impossible), and (b) to develop one recommendation for the whole farming community despite differences in farming systems and determining goals and circumstances (inappropriate). The number of target groups defined will depend on the amount of variation in farmers circumstances (the more variation, the more groups) and the amount of research resources (the more resources, the more groups can be afforded).

Purpose of target grouping

"Target grouping" divides the heterogeneous farming population into more homogeneous subgroups on the basis of those factors which determine the farming systems (like natural and socio-economic circumstances, goals and preferences etc). It is not done for its own sake, but in order to identify differences between and highlight similarities within groups which are significant with regard to the development of agricultural innovations. It is therefore essential not only to identify differences between groups of farmers, but also to analyze how these determine farming systems or practices and opportunities for their improvement.

Target grouping can be done at different levels of the project work

The **general target group analysis** of a project decides which group of people the project is going to support. This target group definition also determines what kind of farmers are to participate in the research efforts. This definition is, however, often too broad and unspecific for research purposes.

Often it is only a particular group of farmers within or across the target groups defined in the general project target group analysis which suffers from a particular problem or which has a specific potential. For this reason it is rather required to characterize subgroups of farmers (called "recommendation domains" by CIMMYT) **specific to an identified problem or potential or to an innovation to be tested**, i.e. groups of farmers which

- are affected by the same production problem, or
- have a particular potential that is not yet utilized, or
- are likely to adopt a specific innovation developed.

This kind of problem, potential or innovation specific "target grouping" helps

- to determine in the analysis of demand for innovation whether the significance of the target group justifies the development of an innovation;
- to analyze whether a potential innovation matches with the requirements of the target groups during the identification of options;
- to select appropriate farmers belonging to a relevant target group for participation in the experimentation programme, and
- eventually to evaluate whether the developed innovation was adopted by its target group or how it was adapted by the target group to its specific conditions.

Procedure

No universally applicable recipe can be given for the identification of different target groups. A workable approach for target grouping appears to be a stepwise one as shown in Figure 6.9, looking successively for differences between groups of farmers with regard to natural conditions, socio-economic circumstances and goals and priorities.

A list of criteria useful for target grouping shown in Table 6.2 gives some guidance. In the target group analysis the aim should be to determine a few (3-5) obvious key characteristics that differentiate different groups of farmers rather than to apply a comprehensive list of criteria.
(Annex 6.1 provides a detailed example of target grouping.)

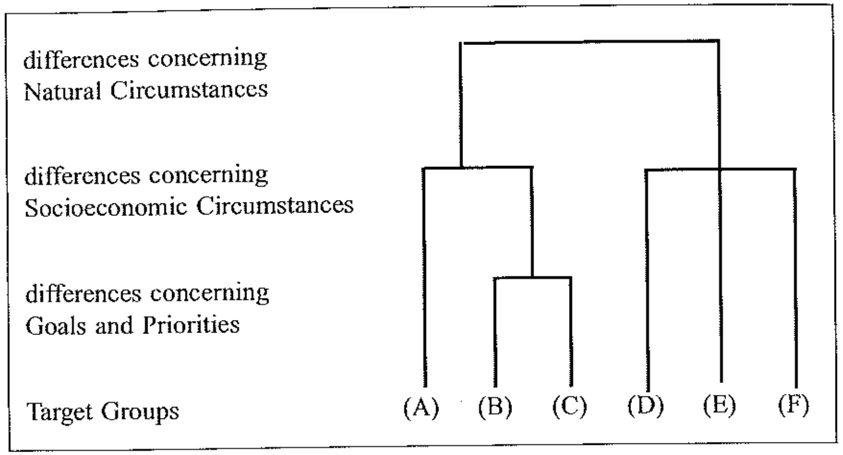
Table 6.2: Criteria useful for target grouping (adapted from CIMMYT, 1985)

Natural conditions
- climate
  - rainfall (duration, distribution, intensity, risk of drought, risk of flooding);
  - temperature (frost incidence);
- soil
  - nutrient supply capacity;
  - texture, structure;
  - drainage, slope, depth;
  - toxic elements, salinity;
- biology
  - pest / disease / weed incidence.

Socio-economic circumstances
- access to land; land tenure;
- access to produce and input markets;
- access to family / hired / shared labour;
- off-farm and non-farm employment;
- access to cash;
- access to credit;
- access to irrigation;
- degree of farm mechanization;
- community customs and obligations.

Goals and priorities
- food preferences;
- income targets;
- risk aversion;
- social objectives.

Figure 6.9: Distinguishing target groups



6.1.4 Analysis of problems and potentials

Problems and potentials are analyzed either
- in group discussions within the dialogue on innovation with farmers or
- as a component in the synthesis of the exploratory survey.

The contents of an experimentation programme should be the **logical and evident consequence** of the analysis of demand for innovation.

The following five steps have proven to be a suitable approach to analysis:

(1) **"Brainstorming"** = list agricultural problems and potentials;
(2) **"Screening"** = check and streamline the initial list;
(3) **"Digging deeper"** = look for more information;
(4) **"Defining target groups"** = define which farmers have a particular problem or potential;
(5) **"Ranking"** = assess the importance of a particular problem or potential.

(1) Brainstorming

In the first step a "brainstorming" session is held to draw up a list of agricultural production problems and of potentials which are not utilized. The aim is to make as **comprehensive a list** as possible. The relevance or importance of a problem or potential are not considered at this stage. (→ Example 6.3)

(2) Screening

The aim of this step is to streamline the initial list and to improve the phrasing of the statements.

During the screening the following questions are asked:
- whether the statements are appropriate and understandable;
- whether the statements can be formulated more specific;
- whether all problems are within the reach of the given means;
- whether there are any repetitions.
(see Example 6.4)

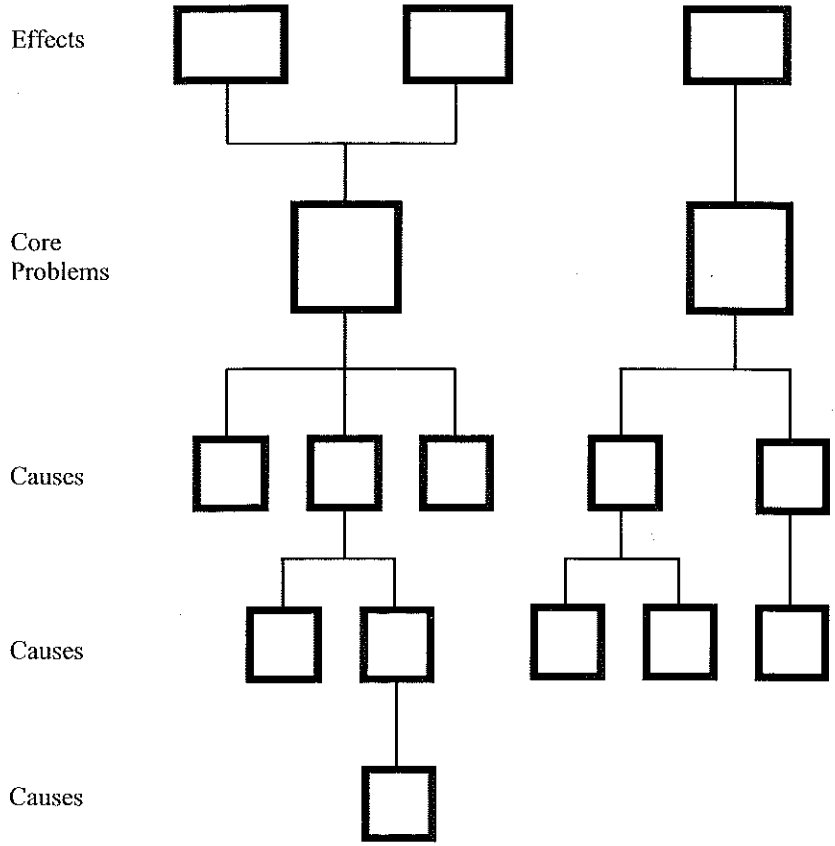
(3) Digging deeper

The aim of this stage is to find **leverage points** for the identification of available options which appear to be suitable to solving a problem or utilizing a potential.

The statements in the list of problems and potentials will usually not show the direction of potential options. It will therefore be necessary to look deeper into the **causes** of the identified problems and to seek **factors** that justify the assumption that there is a potential which could be better utilized. A **comprehensive analysis** ensures that the subsequent steps lead in the right direction.

The results of this step are set out in a **problem tree** (see Figure 6.10) **or summarized verbally**. Elaborating a problem tree in a group discussion requires specific skills on the part of both moderator and participants. A verbal summary is more easily achieved especially in discussions involving farmers and field level staff (see Example 6.5).

Figure 6.10: Graphic presentation of cause-problem relationships using a "problem tree"



(4) Defining target groups

"Target grouping" at this stage defines groups of farmers which are affected by a particular problem or which have a specific potential. An appropriate "target grouping" will help:

- to assess the significance of an identified problem or potential in respect to the importance and relevance of the target group;
- to involve the relevant group of farmers in the subsequent steps of the work.

Principles and procedures of target grouping are explained in detail in Chapter 6.1.3 "target grouping".

(5) Screening and ranking of problems and potentials

A good dialogue with farmers or a thorough farming systems diagnosis will produce a list of problems and potentials too big to be addressed by a trial programme.

The problems and potentials identified must therefore be arranged in order of priority on the basis of the criteria defined in a "dialogue on innovation" in order to select options for experimentation. The criteria should take account of factors such as:

- the importance of the target group in question (i.e. what is the proportion of the target group to the total population?);
- the importance of the respective crop or farm activity within the farming system
- the importance of the problem or potential as it is viewed by farmers
- the significance of the problem or potential in terms of income or subsistence, as it is viewed by researchers.

A matrix as shown in Figure 6.11 can be used for this step. The final ranking of the importance of a problem should be thoroughly thought through and discussed, and not just based on a mechanical addition of the individual rankings of the different aspects considered.

Figure 6.11: Sample matrix for ranking problems (adapted from Tripp and Woolley, 1989)

Problem or potential	Target Group Definition	Criteria					Relative Importance of problem/potential (rank)
		Significance of Target Group	Importance of Crop/ Enterprise	Significance of Yield of Income Loss	Significance felt by Target Group	(?)	

xx = very important x = important o = unimportant

6.1.5 Assessment of potential options before experimentation

The assessment of potential options before experimentation addresses two questions:

- the definition of criteria an innovation needs to comply with and
- the screening of potential options for experimentation.

The most appropriate tool for this analysis is the dialogue on innovation with panel or group discussions with potential target groups.

Definition of criteria for screening of potential options

The basis for this activity is a **brainstorming** session with farmers, which results in a **list of criteria**. If it is considered necessary, researchers may add to the list of criteria suggested by farmers.

A comprehensive list usually requires a **rating or prioritizing** of the identified criteria (a) because the various criteria will be of different importance and (b) because it is impractical to work with a list which is too long in the subsequent screening of options.

A simple tool for rating and prioritizing is a rating scale as it is shown in Figure 6.12. The rating scale translates (subjective) attitudes into a numeric form. This permits a researcher to assess and compare the relative importance of the different chosen criteria. A scale using about 5 grades allows, on the one hand, some degree of differentiation and does not, on the other hand, exceed the ability of participants to differentiate.

The rating of the criteria is used (a) to organize the criteria in order of their importance and (b) to eliminate those criteria which are considered less important. An appropriate list for the subsequent screening will eventually contain 5 up to 10 key criteria – the higher the number of potential experimental treatments, the lower the number of criteria to be applied.

Figure 6.12: Rating scale for screening of cowpea varieties

	very important		fairly important		not important
	(2)	(1)	(0)	(–1)	(–2)
does not fall apart at cooking	❑	❑	❑	❑	❑
tasty leafs	❑	❑	❑	❑	❑
high yield	❑	❑	❑	❑	❑
drought resistance	❑	❑	❑	❑	❑
red grain colour	❑	❑	❑	❑	❑
compatibility with cotton	❑	❑	❑	❑	❑
•					
•					

Screening of potential options

The developed list of criteria is used for the screening of potential options for experimentation.

Where examples of potential options are available already (for instance at research stations), they can be used for a screening exercise involving farmers. Most appropriate are again the tools of the dialogue on innovation, using groups or panel groups of farmers.

The final screening is done by the research team. Those screening criteria which were not important to farmers but crucial in view of the researchers are to be added here. Often not mentioned by farmers are criteria pertaining to sustainability, effects on the local produce markets, sufficiency of research resources etc (further examples of screening criteria were given in Chapter 2.4.2).

A simple tool to compare different options for experimentation is the **matrix technique** shown in Table 6.3. The different options identified potentially useful in solving a specific research question are indicated on the x – axis of the matrix. The screening criteria are indicated on the y – axis, from top to bottom in order of their importance. Different symbols (like +++, ++ and +) show the correspondence of an option with a specific criterion.

The final ranking of the different options or the decision about the activities to be initiated is shown on the last line of the matrix.

Table 6.3 shows a decision matrix as it was developed by the Bean Improvement Project in the Great Lakes Region of Africa. The final decision (last line of the matrix) about the activities to be initiated was based on a thorough discussion of advantages and disadvantages and not on a mechanical addition of the individual ratings given to the different technologies. Eventually "NPK-fertilization and foliar application of fungicides were dropped as options because of the high level and costs of inputs needed for success" (Graf, 1991). Uncertainty (→ climbing beans) was, on the other hand, not considered a reason to drop a topic from the agenda but rather to initiate exploratory activities. Climbing beans, initially burdened with some questionmarks, eventually turned out to be the biggest success.

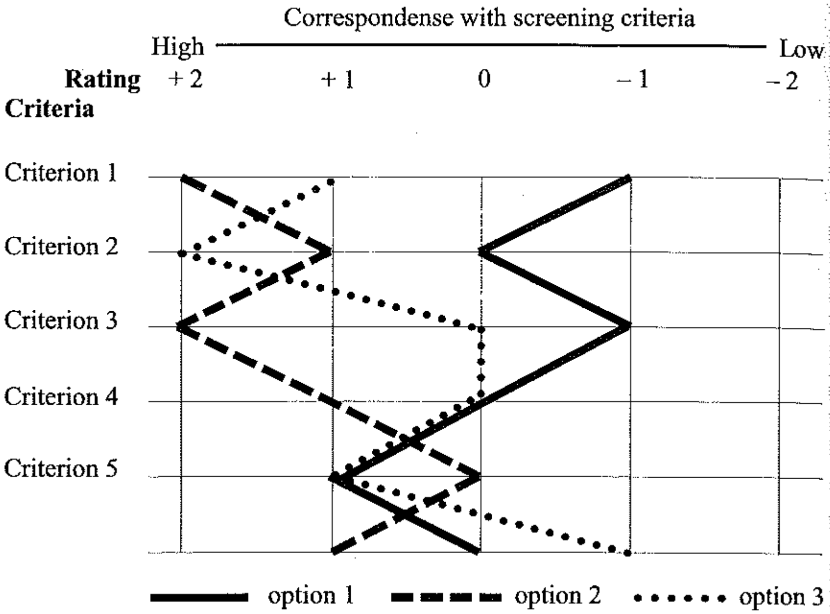
Table 6.3: Decision matrix for " screening of potential research options for the improvement of bean production in Rwanda, 1986" (adapted from Graf, 1991)

Criteria:	Options				
	Climbing Bean	Disease resist. bush beans	Seed treatment bean fly/root rot	Foliar applic. of fungicides	NPK Fertilizer and Manure
The option controls[(1)]	D + (F)	D	P + D	D	F
Chance of success[(2)]	?	+ +	+ + +	+ + +	+ +
Ease of carrying out research	+ +	+ +	+ + +	+ +	+ +
Compatibility with farm. system	?	+ + +	+ + +	+ + +	+ +
Required inputs / institut. support	+ + +	+	+ +	+	+
Profitability	+ +	+ +	+ +	+ +	+ +
Stability	+ ?	+ +	+ +	+	+
Decision[(3)]	OF-study	Continue OS/OF	OS/OF	Drop	Drop

[(1)] D = Diseases, P = Pest, F = Fertility
[(2)] + + + = good/favourable, + = poor/unfavourable, ? = uncertain
[(3)] OS = On-Station, OF = On-Farm

A graphical technique to compare the different options is the **profile diagram**, as shown in Figure 6.13. The basis is a rating scale, according to which every option is assessed. The rating scale is put on the x – axis, the different criteria for screening in order of importance from top to bottom on the y – axis of the diagram. Different lines are used to mark the ratings of the different options in the diagram. The resulting "profiles" for every option are a good basis for the eventual thorough discussion which will result in a final ranking of the different options.

Figure 6.13: Profile diagram for comparing different options for experimentation



6.1.6 Qualitative assessment of experimental treatments by farmers

In the early stage of an experiment the number of experimental treatments is usually relatively large and the number of farmers involved relatively small. These conditions do not facilitate a quantitative assessment of the tested options. Hence farmers assessment of the experimental treatments will be of qualitative nature at this stage.

An appropriate tool for the qualitative assessment is the dialogue on innovation with groups or panel groups. A first result can be to verify whether the list of screening criteria developed earlier is still valid at this stage or whether farmers views changed while participating in the trial. The kind of questions asked are:

- What do you think of (treatment x, y, z...)?

- What are the advantages of .....?
- Asking "why" or "can you explain this" after an answer will help to understand the reasons for farmers views.

Farmers spontaneous comments are a good indicator of what farmers consider to be the most important features of a specific experimental treatment.

Further criteria (obtained during the screening of potential options or specifically defined for this purpose) may be applied for assessment after spontaneous comments were given.

Eventually farmers views can help to reduce and adapt the choice of experimental treatments. Farmers' contributions can be stimulated with questions like:

- Do you think this treatment deserves to be repeated?
- Which treatments would you like to try again, or suggest to be dropped next season?
- Which modifications do you suggest?

Farmers' open and honest rejection of trial options requires that researchers declare their neutrality in respect to the experimental treatments and their receptivity to open and constructive criticism (see also Chapter 3 – Communication with farmers).

6.2 Analysis of information from standardized data collection

The techniques described in the following deal with the analysis of information from standardized data collection as it is applied in experiments or formal surveys.

The analysis follows largely the basic procedure outlined in Chapter 2.4.4 "Assessment of the options". The analysis consists of the preparation of data for the analysis, the actual data processing/analysis and the tabular or graphical representation.

This guide presents some standard techniques which proved to be useful for the analysis of on-farm experiments. It cannot give a comprehensive and detailed description of statistical techniques. For this reference is made to special literature.

Techniques with regard to the preparation of data are described in somewhat more detail. This important aspect of the data analysis is not covered sufficiently in the literature usually available in projects and, consequently, does often not receive enough attention. Preparation includes transforming data into a format convenient for the data processing on microcomputers.

6.2.1 Data preparation

At this stage the raw data obtained in experiments or formal surveys are prepared for the actual data analysis in a series of consecutive steps.

Check for completeness

The raw data are checked through in order to ascertain whether all the required data defined in the experimental or survey-plan were really collected. Missing numeric data can be supplemented to some extent (→ "Missing value technique"). Before this is done, it is advisable to check whether the data cannot be completed with the help of the staff responsible for recording.

Check for problem data

The following considerations refer specifically to the analysis of data from on-farm experiments.

In on-farm experiments it is more common than under station conditions that the validity of data is affected by incorrect implementation or by the destruction of experimental plants.

Incorrect implementation includes the wrong treatment application as well as the non-uniform application of non-treatment field operations. There are two basic ways of coping with such problem data (see also Table 6.4): (a) if only a few experimental units per farm are affected, the data in question are declared missing and supplemented using the missing value technique, (b) otherwise it will be necessary to disregard the whole data set for this farm. In rare cases it will be possible to save the data by redefining the experimental objectives, when all experimental units of a treatment were affected by the same implementation error.

Examples with regard to the **destruction of experimental** plants and possible remedies are given in Table 6.4. Before any adjustments of affected data are made, it must be determined whether the loss of these plants is possibly related to the treatments applied. Poor germination in certain plots of a variety trial, low plant population in the control plot of a fertilizer trial or a high level of plant damage by pests in a pest control trial

are some examples of plant destruction which is possibly related to experimental treatments.

Data adjustments are only justified if it can be safely assumed that the loss of / or damage to plants is not related to the experimental treatments applied. In this case there are two basic possibilities:

(a) if the loss or destruction of harvest products (for example by theft, premature harvest by farmers or destruction by animals) or the destruction of whole plants occured in the **yield formation phase** of the crop development, it can usually be assumed that the development of neighbouring plants will not have benefited by the destruction. The affected data are adjusted with a simple mathematical transformation in order to project the yield which would have been achieved without destruction:

$$Y_{adj} = Y_{act} \cdot \frac{P_{act} + P_{dest}}{P_{act}}$$

Y_{adj} = *adjusted yield – without destruction*
Y_{act} = *actual (unadjusted) yield*
P_{act} = *actual number of plants*
P_{dest} = *number of destructed plant*

(b) if the destruction of plants occured during the **vegetative development** of the crop it may be assumed that plants immediately adjacent to the damaged plants perform better than they would otherwise. A considerable loss of plant population is, however, very common in farmer-managed experiments and to an extent, it can be tolerated as a usual condition of on-farm trials. Data adjustments are, therefore, better based on the visual identification and subsequent counting or measuring of missing hills or vacant areas rather than on the simple comparison of actually achieved and the theoretically possible plant populations on a specific plot. There are three different ways to deal with data in the case of destruction during the vegetative development:

- No adjustments should be made, if the percentage of missing hills or vacant areas is very small (< 10 %).
- A covariance analysis is suggested for data adjustment if the percentage of missing hills or vacant areas is between 10 and 20% of the theoretical number of hills or the plot size.
- If more than 20% of the expected hills or the plot area is vacant, the data for the respective plots are declared missing and the missing value technique is applied.

Check for data consistency

In this step it is checked whether all data of a given data set are consistent in themselves.

With regard to **survey data** this means ascertaining that the answers given to different questions within one interview are not contradictory. Before a decision is made to disregard an inconsistent questionnaire, an attempt should first be made to rectify contradictory answers in cooperation with the responsible interviewer.

It often happens with data from **on-farm experiments** that some data appear to be too low or too high in comparison to other data of the same data set.

There is a considerable debate in the liteature as to whether it is justified to adjust data that appear to be inconsistent. Some inconsistency is certainly tolerable in on-farm trials if it is expected that a successful innovation shows a relatively high advantage as compared to the present technology.

Inconsistencies can have a variety of different causes, like:

- incorrect measurements or data transcriptions;
- undiscovered errors in trial implementation;
- the heterogeneous farm environment;
- a behaviour of experimental treatments which does not accord with the researchers expectations.

It is not acceptable to manipulate or disregard data just because they do not conform with the researchers preconceived ideas.

If data are checked early enough it is often possible to rectify incorrect measurements or data transcriptions by going back to the field notes of the recording staff or by re-measuring harvest samples.

Table 6.4: How to deal with problem data

Problem	Remedies
Incorrect implementation	(a) declare missing, if 1 (max.2) plots per farmer affected; missing value techn. (b) redefine objective if all plots of a treatment in a trail are affected alike (c) disregard data set if (a) and (b) not possible
Destruction of plants • poor germination • physical damage • damage by pests, diseases or animals • parts of harvest prematurely harvested or stolen • etc.	**Adjustment only if problem not related to poor germination treatment !** (a) only harvest produce, or plants affected during yield formation = simple projection of theoretical, based on actual data x expected over destructed no. of plants (b) plants affected during vegetative growth (i) no adjustment for low degree of destruction (< 10 % of hills missing or area vacant) (ii) analysis of covariance for moderate degree of destruction (10 – 20% of hills missing or area vacant) (iii) failed plots are declared missing for high degree of destruction
Unforeseen heterogeneity of farm environment • soil differences • drainage differences • etc.	(a) declare data missing if 1 (max. 2) plots per farmer affected: missing value tech. (b) analysis of covariance, if characters were measured before treatm. application which are closely related to the respective variable (like plant height to crop yield) (c) disregard data set if (a) and (b) not possible

Data adjustments are only justified if the inconsistency observed can be clearly related to heterogeneity of the farm environment (like unforeseen differences with regard to soil fertility or drainage conditions). There are three possible ways to deal with such data:

- The data in question are declared missing and supplemented using the missing value technique, or
- a covariance analysis is used if characters which are closely related to the respective variable (like plant height to crop yield) were measured **before or at** treatment application;
- the questionable data set is disregarded if both adjustment techniques are not applicable.

Missing value calculation

Where necessary missing values are calculated using the folowing formula:

$$\text{Missing value} = \frac{t \cdot T + r \cdot R - S}{(t-1)\cdot(r-1)}$$

t = *number of treatments*
T = *sum of the results of the treatment with the missing value*
r = *number of replicates*
R = *sum of the reults of the block with the missing value*
S = *sum of the results of all plots in the trial*

Most of the relevant statistical computer programme facilitate the computation of missing values (for example the modules ANOVA-2 and MISVALEST of MSTAT) or delete observations with missing values from the analysis (like the GLM-ANOVA in Solo).

Preparing the data matrix

Almost all statistical analysis procedures are working on the basis of a data matrix as it is shown in Table 6.6. The lines contain the results for the different cases or "units of investigation" (i.e. one line contains all the results for one plot in the case of data from on-farm experiments or all information from one interview in the case of a survey), the columns the different variables.

The major steps in the preparation of the data matrix are:

(a) the elaboration of a codeplan;

(b) coding of information;

(c) entering the information into the matrix.

Codeplan

For the computer analysis all information needs to be available in an appropriate form. A data transformation is therefore especially necessary for all non-metric data.

Most results from **on-farm experiments** will already be available in metric form and do not require coding. Coding is, however, required for the designation of the experimental plots.

Survey data are often not available in a form appropriate for a computer analysis. The multitude of possible answers to open question of the questionnaire will first of all have to be assigned to a few answer categories, if possible answers were not categorized already during the questionnaire design. Subsequently a code is given to every answer category.

The sample codeplan in Table 6.5 shows
- which variable will be accomodated in which column of the data matrix, and
- which figures (="codes") will be assigned to which variable descriptions.

In this example every plot is identified by 6 variables (season, site, farmer, plot number, variety and time of planting) accommodated in the first six columns of the data matrix (see Table 6.6). Figures assigned to every variable description are shown under "designation". For example with regard to "seasons" a "1" will be used in the data matrix for 1992 and a "2" for 1993; for site a "1" is used for x-village, a "2" for y-village. Yield data contained in columns 7 – 15 of the data matrix do not require coding. Proper preparation and storage of the codeplan helps to ensure that the data entered into the data matrix are well understood by everybody involved in the data processing.

Table 6.5: Codeplan for on-farm trial "Cowpea varieties for interplanting with cotton" (adapted from DAO, DLASO and GASP trial programme, Lamu, Kenya)

Column	Variable	Designation	
1	Season	1 = 1992 2 = 1993	
2	Site	1 = x-village 2 = y-village	
3	Farmer	**x-village**	**y-village**
		1 = (name)	(name)
		2 = (name)	(name)
		3 = (name)	(name)
		4 = (name)	(name)
4	Plot number	1 – 6	
5	Copea variety	1 = K 80 2 = M 66 3 = farmers	
6	Time of cowpea interplanting	1 = 3 weeks after cotton 2 = farmers time	
7	Cowpea yield	kg/ha	
8	Cotton yield	kg/ha	
9	Cotton grade 1	%	
10	cowpea yield	kg/plot	
11	cowpea moisture	%	
12	cowpea estim. shelling	%	
13	cowpea net plot size	m^2	
14	Cotton net plot size	m^2	
15	Cotton yield	kg/plot	
16	Cotton yield grade 1	kg/plot	

Table 6.6 contains part of the data matrix used for the on-farm experiment "Cowpea varieties for interplanting with cotton". The 16 columns of the data matrix contain the variables described in the codeplan. The data matrix contains only metric data. The sample matrix was created on a LOTUS spreadsheet. It was transformed into ASCII format and imported into MSTAT for the actual data analysis.

Note: raw data with yield parameters on "**per plot**" basis were entered in column 10 – 16 of the matrix. The spreadsheet programme was used to perform the conversion into yield data on "**per hectare**" basis on which the actual statistical analysis is done. Similar transformations can be done with almost all statistical programmes. The raw data can be entered right from the field record form, if the order of variables in the record form corresponds with that of the data matrix.

Table 6.6: Data matrix for on-farm trial "Cowpea varieties for interplanting with cotton" (adapted from DAO, DLASO and GASP trial programme, Lamu, Kenya)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	1	1	132	1579	89	1.6	15.5	55	64.8	42.1	6.65	5.94
1	1	1	2	2	1	482	843	85	5.8	14.9	55	64.8	42.1	3.55	3.03
1	1	1	3	3	2	148	772	95	1.85	17.8	55	64.8	42.1	3.25	3.09
1	1	1	4	3	1	103	1223	95	1.25	15.3	55	64.8	42.1	5.15	4.89
1	1	1	5	2	2	140	985	93	1.7	15.7	55	64.8	42.1	4.15	3.88
1	1	1	6	1	2	65	1080	94	0.8	16.9	55	64.8	42.1	4.55	4.26
1	1	2	1	1	1	325	724	100	3.9	14.7	55	64.8	42.1	3.05	3.05
1	1	2	2	2	1	1007	1199	100	12.2	15.4	55	64.8	42.1	5.05	5.05
1	1	2	3	3	2	183	760	100	2.2	14.7	55	64.8	42.1	3.2	3.2
								⋮							
1	2	3	4	3	1	0	1140	100	0	17	100	64.8	42.1	4.8	4.8
1	2	3	5	2	2	212	3822	100	1.42	15.7	100	64.8	42.1	16.1	16.1
1	2	3	6	1	2	366	3122	100	2.42	14.7	100	64.8	42.1	13.1	13.1
1	2	4	1	1	1	315	1062	100	3.8	15.1	55	64.8	40.5	4.3	4.3
1	2	4	2	2	1	166	1430	100	2	14.8	55	64.8	48.6	6.95	6.95
1	2	4	3	3	2	0	1934	100	0	15	55	64.8	48.6	9.4	9.4
1	2	4	4	3	1	488	1157	100	5.9	15.2	55	64.8	30.2	3.5	3.5
1	2	4	5	2	2	144	0	100	0.95	14.6	100	64.8	48.6	8.75	8.75
1	2	4	6	1	2	129	1667	100	0.85	14.3	100	64.8	48.6	8.1	8.1

Coding

The codes are
- either entered directly in the proper record form or questionnaire, which means that provision was already made for this when the questionnaire was designed, or
- first transcribed by hand into a codeform equivalent to the data matrix subsequently used.

With some computer programmes (like dbase) it is possible to enter non-metric information and have the computer transform the data. Entering coded information, however, is usually less time consuming.

6.2.2 Data analysis

Three components of data analysis are explained in the following section:
- the statistical analysis of agronomic data;
- the economic analysis and
- and the analysis of farmer' assessment.

6.2.2.1 Statistical analysis of experimental data

The statistical analysis of agronomic data is the basis for the **assessment of the feasibility of a potential innovation under given natural environment(s)**. This includes aspects such as:
- the production of a trial innovation as compared to the present technology;
- the adaptability of a trial innovation to different environmental conditions;
- the expected production risks of the potential innovation.

The statistical analysis of experimental data is furthermore the basis for the subsequent economic assessment.

Analysis of variance (ANOVA)

The analysis of variance will usually be the first step of the statistical analysis. It determines to what extent factors like experimental treatments and site specific conditions contributed to the observed differences between experimental treatments.

The statistical significance of the observed treatment differences is determined with the **"F-Test"**. The F-test compares the computed F-value (= Treatment MS over Error MS) with the tabular F-value. If the computed F-value is higher than the table value at the 1% level of significance (= probability or "p"-level) the treatment differences are said to be highly significant. Such results can be indicated by placing two asterisks on the computed F-values in the ANOVA – table. In view of the normally high variation of results, a p-level of 5% (i.e. one asterisk on the computed F-value) will be acceptable for on-farm trials.

Most statistical computer programmes calculate the p-level automatically and show it in the ANOVA-table, so that the comparison of computed and tabular F-values will usually not be necessary anymore.

The **F-test** decides, however, only **whether there were statistically significant differences** between the treatments of an experiment. A subsequent **comparison between treatment** means will have to show **which treatments were significantly different** if a trial was comprising of more than two treatments.

The appropriate analytical procedure for the analysis of variance is already determined during the design of experiments (see Chapter 5.2).

Calculating the **interaction between farms and treatments** is not possible **without replication of treatments on the same farm**. If there was no replication within the same farm but treatments appeared to perform differently on different farms, suitable farm-specific factors (like quality of weeding, time of planting or a management factor combining the quality of various key operations) should be identified and subsequently included in the analysis of variance as an additional variable.

Replication of treatments within the same farm allows the computation of treatment x farm interaction. This reveals **whether** there is an interaction. In case of the interaction term being significant, it will again be necessary to determine which farm-specific factors contributed to it. The conclusion depends on the objective:

- if the aim is to develop an innovations with a **wide adaptability**, then technologies are to be identified whose average effects over farms are high and stable;
- if the aim is to develop **specific technologies for specific types of farms**, then conditions are to be defined under which a specific technology will be applicable.

An important trial objective is often to examine which treatment is adapted to which kind of environment. The analysis of variance over different sites or season shows **whether** treatment effects change under different environmental conditions. This analysis requires, however, that the same treatments and the same experimental design are applied over all sites or seasons.

The analysis over different **sites or agroecological zones** with sites or zones as an experimental variable allows a computation of the interaction between treatments and sites (or zones). Specific environmental conditions (like soil parameters) are preferably defined before experiments are carried out and trial farmers selected accordingly (see Chapter 5.2.2). It is usually more difficult to group farmers into appropriate environmental categories after trial implementation. A non-significant interaction – F means a high degree of treatment adaptability to different environments. A significant interaction term calls for further analysis in order to determine which treatments are best adapted to which environmental conditions.

The variability of climatic conditions over years is relatively unpredictable. The **combined analysis over years at a given site** or a given agroecological zone therefore aims at the identification of treatments whose average effect over years is high and stable at this particular site or zone. If the treatment x year interaction is relatively low it can be expected that the ranking of treatments is stable over years and the interaction can be ignored. If the interaction is significant, it is likely that the ranking of treatments changes over years and it would be necessary to examine the nature of the interaction.

Comparing treatment means

When the analysis of variance yields significant F-values, the comparison of treatment means is a follow-up procedure to analyse **which treatment means differ from each other**. **Pair comparisons** (i.e. comparing two treatment means at a time) are the most commonly used comparisons in agricultural research. There are two major groups of pair comparisons:

- **planned comparisons** in which specific pairs of treatments to be compared are identified already before experimentation, and
- **unplanned comparisons** in which every possible pair of treatment means can be compared to identify significant differences, without prior planning.

The most commonly used **planned comparison** is the least significant difference (LSD) test, because of its simplicity. This test can, however, easily produce misleading results if it is wrongly applied: if it is used to compare every possible pair of means, it is likely to show significant differences even if the F-tets did not yield significant treatment differences. The likelyhood that the LSD-test shows significant treatment differences increases with an increasing number of treatments. To avoid misleading results it is recommended to apply the LSD test only if the F-test for treatment differences was significant and if the number treatments is smaller than 6 (Gomez and Gomez 1983). Most appropriately it is used to compare the control treatment with the other treatments of a trial.

Safer in their application are **unplanned comparison** which allow the comparison of every posible pair of treatment means without prior planning for it. The relevant statistical computer programmes usually contain a number of mean comparison tests (MSTAT, for example, provides under "Range Tests": Duncan's Multiple Range Test, Tukey's Test and Student Newman-Keul's Test). Some care is, however, required if the procedures are applied on **factorial experiments** (i.e. trials involving more than 1 experimental factor, see Chapter 5.2.4): If the F-test shows non-significant interaction effects, only the main effects of the different factors should be compared (e.g. the means of the levels of factor A over all levels of factor B). The mean separation procedure is applied on the factor level combinations only if the F-test showed significant interaction effects (see Annex 6.1).

Estimating stability

If the interaction between treatments and farms, sites or years proves to be significant in the analysis of variance, the stability of the different treatments will need further analysis and comparison.

A simple way to estimate and compare **stability of treatment means over different farms, environments and years** is the computation of **frequency distributions**. The Box-and-Whisker-Plot shown in Figure 6.14 is a tool to **identify treatments which are stable over a range of conditions.** It is calculated by most of the suitable computer programmes and can be used to show median, range and quartiles of treatment values across farms. The treatment mean can be included in addition to the median. A narrower range of treatment values means higher stability or better adaptability to different conditions. If two treatments show similar mean values, the one with the narrower range is preferable. This technique is appropriate in particular for the verification stage of an experiment with a relatively large number of participating farmers.

A tool which helps to determine **which treatments are best adapted to which environments** is shown in Figure 6.15. The yields of the treatments tested are plotted **against farmers, villages or agroecological zones**. This kind of graph allows the comparison of adaptability of treatments over different environments. It shows which treatments were "stable" over all farmers, villages or zones, and at which farms, villages or zones a treatment performed well or poorly. Thus it helps to identify the specific conditions to which a particular treatment is well adapted and those for which it is less suited. This technique provides good results with relatively few farmers, villages or zones to be analyzed. (Similar is the modified stability analysis of Hildebrand and Poey (1985) in which mean yields at each location are used as "environmental index" against which individual treatment yields are plotted.)

Figure 6.14: Box-Whisker-Plot

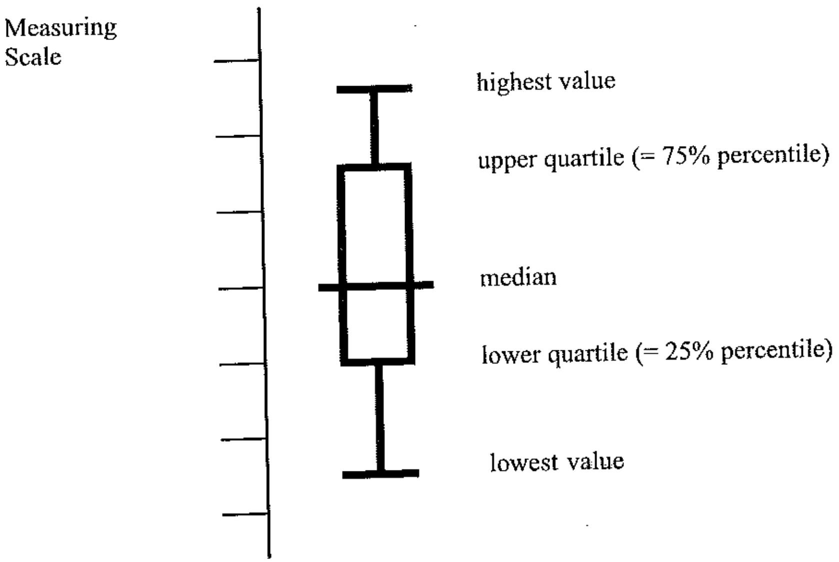
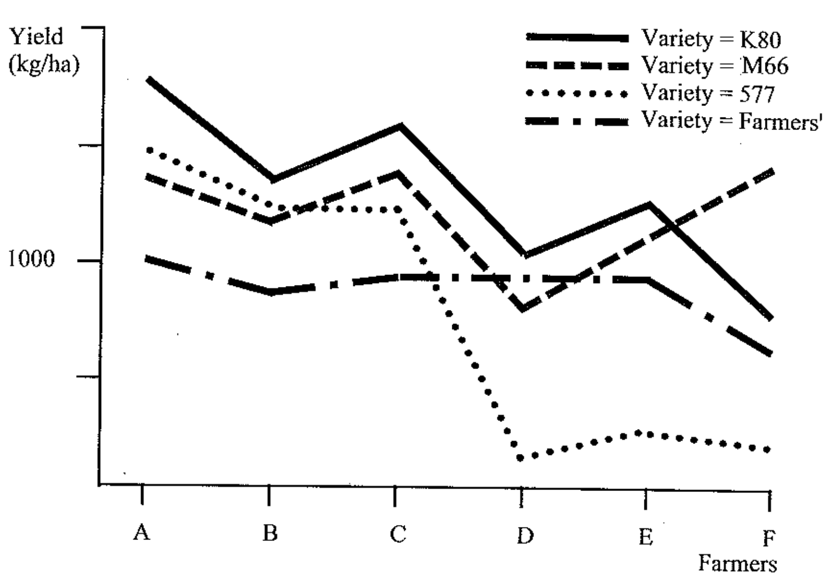


Figure 6.15: Graphical assessment of the adaptability of different cowpea varieties to different farm conditions



Estimating risks chances of success

A key criterion for the quality of a potential innovation is the risk of failure or, seen positively, the chance of success to be expected.

The "risk" is defined as the probability that a potential innovation fails; conversely, the "chance of success" is the probability that a potential innovation will succeed. An appropriate basis of comparison is the farmers' present practice, which is usually the control treatment. "Failure" therefore means that the potential innovation did not achieve the yield level obtained through farmers' present practice on a particular farm.

A better basis for comparison would be the result of farmers present practice **plus** a defined margin (e.g. 30%), because it would be expected that an innovation is not only superior, but clearly superior to present cultivation practice.

The simple calculation is as follows:

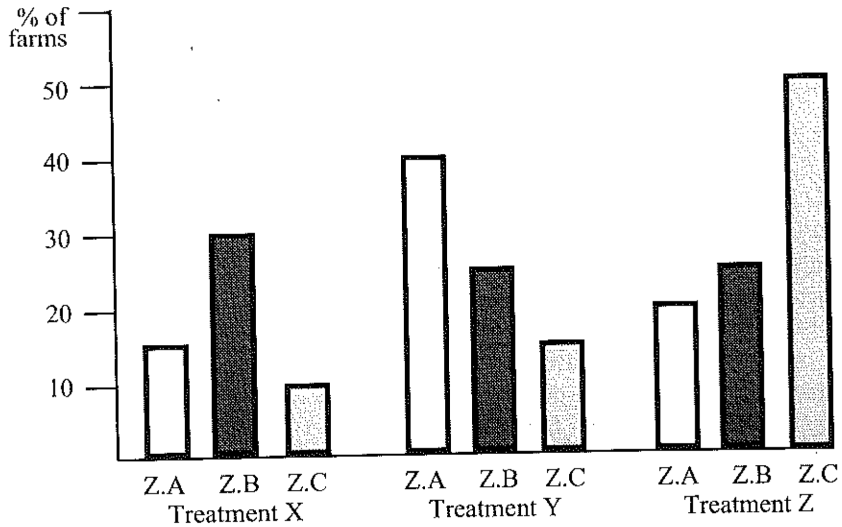
$$Risk\ of\ failure = \frac{No.\ of\ farms\ at\ which\ innovation\ failed}{Total\ no.\ of\ farms\ involved\ in\ the\ trial} \cdot 100\%$$

The results are represented in tabular form (see Table 6.7) or as bar chart (Figure 6.16). The consideration of an additional variable (like agroecological zones) is possible in both cases.

Table 6.7: Table for "risk of failure" in different agroecol. zones (% of farms at which exper. treatments did not obtain a yield level 30% higher than control)

	Treatment X	Treatment Y	Treatment Z
Zone A	15	42	20
Zone B	31	28	24
Zone C	12	13	51

Figure 6.16: Bar chart for "risk of failure" in different agroecol. zones (% of farms at which exper. treatment did not obtain a yield level 30% higher than control)



Analysis of intercropping trials

Trials with two or more crops grown simultaneously require a different approach than trials with just a single crop. The analysis of such trials differs from that commonly used for station trials insofar as indicators such as the "Land Equivalent Ratio" (LER) cannot be calculated because there are usually no special plots for single crops. (In an on-farm experiment all treatments tested should be real options to the farmer. Hence, it is not recommended that a treatment be implemented just for calculatory purposes).

In the absence of single crop plots, total yields of different crop mixtures can be compared by converting grain or tuber yields to calories or protein. This conversion however has a disadvantage similar to that of the LER: the calculation of the total yield (in calories) or of an (artificial) ratio may not reflect farmers' real desires.

An aim often observed is to produce as much as possible of the main or staple crop with a supplement provided by the secondary crop. In this case the effect of the innovation on the yield of the main crop would have to be valued higher than that on the intercrop yield.

Particularly in intercropping trials aspects other than yield are often highly important. Changes in intercropping arrangements can, for example, have significant effects on resource allocation (like additional labour requirements in critical periods or additional chemicals). As such important criteria tend to be overlooked by researchers, the dialogue on innovation plays a particular outstanding role for the assessment of options in this more complex type of experiments.

6.2.2.2 Economic analysis of experimental data

A potential innovation usually involves additional inputs in terms of seed, fertilizer, labour etc. A tested technology may gain a higher yield, but the farmer would not benefit if the additional expenses exceed the value of the additional production. A potential innovation may be more profitable per area of land, but not attractive to the farmer if it involves more labour and thus less profit per unit of labour than the present practice.

Economic considerations are therefore of vital importance in interpreting agronomic trials and making recommendations wherever the tested innovations require the use of additional resources.

A word of caution: the superiority of a potential innovation in monetary terms does not guarantee that it will eventually be adopted by farmers. Economic indicators are the more important the more a specific target group and the farm activity involved is embedded in the market economy. Economic indicators will be of little significance for highly subsistence-oriented farmers or crops exclusively grown for home consumption. It is, therefore, essential to determine and rank indicators for the analysis in the dialogue on innovation (see Chapter 4.2.2) before a decision is made about the mode of the economic analysis and its value in comparison to the agronomic analysis and the farmers' assessment.

Selection of evaluation criteria

The economic analysis evaluates returns on the **production factors of land, capital and labour**. Not all these factors need to be considered routinely for every experiment. The choice of appropriate criteria for the economic analysis is determined by:

(1) the role of a production factor in the specific experiment;
(2) the availability of a production factor in the farm economy of the target group.

(1) Returns are calculated only for those production factors which are actually affected by the trial innovations. A production factor not affected by the innovation tested in the experiment does not need to be considered in the analysis. The production factor "land" is involved in all experiments dealing with crop production. **Returns on land** (i.e. gross margins) are therefore calculated for all these experiments. The calculation of **returns on capital** is useful when a potential innovation requires a substantial amount of additional capital. The **returns on labour** should be calculated, whenever a potential innovation affects the labour allocation. Some suitable economic indicators are presented in Table 6.8. . Table 6.10 shows some examples of production factors affected in different types of experiments and the choice of suitable indicators for economic analysis.

(2) The relative importance of criteria chosen for the economic analysis is determined by the **relative availability** (or scarcity) **of a production factor** in the farm economy. The returns on a factor more scarce in the farm economy should be valued higher in the economic analysis than the returns on a factor available in relative abundance.

The concept of "partial budgeting"

To simplify the budgeting procedures, all considerations of costs and benefits in this context disregard the element of "fixed" costs. This is based on the assumption that potential innovations tested in on-farm experiments will only cause changes in the "variable costs". Budgeting procedures need to be adjusted wherever this assumption does not hold true.

Table 6.8: Choosing economic indicators on the basis of production factors affected by the potential innovation

Production factor affected	Suitable economic indicators
Capital only	– gross margin + returns to variable costs or + marginal rate of return (for **systematically increasing levels** of an experimental factor)
Labour only	– yield / labour ratio
Capital + labour	– gross margin + returns to var. costs or marg. rate of return + (monetary) returns on labour

Table 6.9: Some economic terms

Gross margin / ha = gross retuns/ha – variable costs/ha
The gross margin is the monetary value of a crop per unit of area after deduction of the variable input costs required to produce this crop.

Returns to variable costs = gross returns / variable costs
The returns to variable costs relate the gross returns of a farm activity to its variable cost.

Marginal rate of return = $\frac{\textit{Incremental gross margin between 2 treatments}}{\textit{Incremental costs between these 2 treatments}} \cdot 100\%$

The marginal rate of return indicates which additional gross margin is obtained per unit of additional variable costs between two treatments. It replaces the returns to var. costs in the analysis of experiments with systematically increasing levels of an experimental factor (e.g. fertilizer levels).

Yield/labour ratio = yield of a crop / units of labour applied on this crop
This ratio shows how much yield is obtained in relation to one unit of labour applied. It is used for experiments in which only the factor labour but not capital is affected by a potential innovation.

(Monetary) returns on labour = gross margin / units of labour used to obtain the gross margin
This indicator shows the magnitude of gross margins obtained in relation to one unit of labour applied. It replaces the yield/labour ratio where labour **and** capital are affected by an innovation.

Risks and stability

Some simple methods to compute the stability of treatments over different environments and the risks connected with the application of the tested treatments were shown already in the agronomic analysis. The same methods introduced there are applicable also for the economic analysis of experimental data.

It will not be necessary to consider stability and risks in both the agronomic and the economic analyses. In the more common case that an innovation requires additional resources, the comparison of risks and stability of the different options tested will be more appropriate in the economic analysis.

Table 6.10: Some examples of production factors affected by different trial types and the choice of economic indicators

Type of trial	Production factor affected	Choice of indicator for economic analysis
Variety trial	Capital (costs of new variety higher than the local standard, but no systematically increasing levels of capital)	– gross margin + returns to var. costs
Fertilizer levels	Capital (costs of fertilizer systematically increasing)	– gross margin + marginal rate of return
Methods of fertilizer application (e.g. once or split)	Labour (more for split application)	– yield/labour ratio
Application of organic manure	Labour (for collecting, processing and application)	– yield/labour ratio
Alley cropping*	Capital (for seed or seedlings)	– gross margin + benefit/cost ratio
	Labour (to establish and maintain alleys)	+ (monetary) return on labour

* Alley cropping trials and any trial involving perennial crops would, strictly speaking, require a cash flow analysis. For this reference is made to special farm economics literature (e.g. Stroebel, 1987)

6.2.2.3 Analysis of farmers' assessment

The superiority of an innovation in both agronomic and economic terms does not guarantee that it will be eventually adopted by farmers. A complementary farmer assessment should ensure that those criteria important to farmers are not overlooked in the analysis.

The following describes some methods of farmer assessment which are especially suited for the quantitative analysis of relatively large and representative groups of farmers and few treatments (not more than 4 or 5). The techniques are applicable at an advanced stage of a trial, with only a limited choice of options remaining. Techniques of a more qualitative nature are applied for farmer assessments involving larger numbers of options (see Chapter 6.1.6). Two of the methods described in the following (rating and matrix ranking) require the prior identification of suitable assessment criteria (see Chapter 6.1.5).

Rating

The procedure applied is similar to the one used for the identification of assessment criteria (see 6.1.5). The 5 – 10 criteria considered most important by farmers are set out on a rating scale (Figure 6.17) which is used to gain a farmer-by-farmer rating of the quality of the experimental treatments.

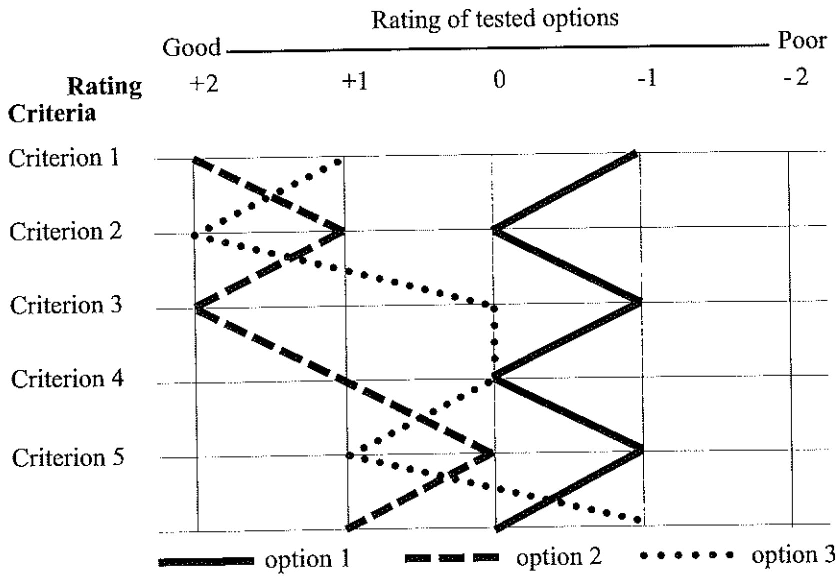
A mean rating is calculated treatment by treatment for every criterion either for all farmers or for suitable subgroups (i.e. all farmers of a village, a zone or defined "target groups").

The mean ratings for the tested options are tabulated or graphically compared in a profile diagram as shown in Figure 6.18. The rating scale is laid on the x – axis of the diagram, the assessment criteria in order of their importance on the y – axis. Different symbols are used to mark the ratings of the different options to be compared. The "profiles" for every option are a good basis for a discussion on the overall rating of the different tested options. This is best done together with the farmers involved in the experiment.

Figure 6.17: Rating scale for farmers' assessment of cowpea varieties

Rating criteria	Varieties	Assessment				
		very good		fairly good	poor	
		(2)	(1)	(0)	(-1)	(-2)
Compatibility with cotton	Var. X	❑	❑	❑	❑	❑
	Var. Y	❑	❑	❑	❑	❑
	Var. Z	❑	❑	❑	❑	❑
Drought resistance	Var. X	❑	❑	❑	❑	❑
	Var. Y	❑	❑	❑	❑	❑
	Var. Z	❑	❑	❑	❑	❑
Taste + flavour	Var. X	❑	❑	❑	❑	❑
	Var. Y	❑	❑	❑	❑	❑
	Var. Z	❑	❑	❑	❑	❑
• •						

Figure 6.18: Profile diagram for comparing farmers' ratings of different options tested in an on-farm experiment



Matrix ranking

Matrix ranking involves asking farmers to rank the experimental treatments with respect to defined assessment criteria. As for the rating, assessment criteria are identified by farmers in advance. The most important 5 – 10 criteria are chosen for the matrix ranking. A rank is given to every treatment with respect to every criterion applied.

Figure 6.19: Example of a matrix ranking of different cowpea varieties in a farmer evaluation

Cowpea Variety	Criteria								
	Over-all rank-ing	Yield poten-tial	Early ma-turity	Pest and disease resist-ance	Com-pati-bility with cotton	Grain colour	Grain size	Time for cook-ing	Taste and flavour
K 80	1	2	1	3	2	1	3	1	1
M 66	2	1	3	1	1	3	3	3	3
K o95	3	4	1	3	4	1	1	1	1
Local	4	3	4	2	3	4	1	4	4

Pairwise comparison

By comparing in pairs each option tested can be judged as better or worse than another. A reason for this judgement is given. In a complete comparison of pairs with a maximum of 3 to 4 treatments to be compared, all treatments are compared with each other: A with B, A with C, A with D; B with C and B with D; C with D. This kind of comparison helps to identify the most important advantages and the most critical disadvantages of all options tested. It can eventually result, again, in a ranking of the different options. This method is useful also for the identification of suitable options for experimentation before trials are carried out. An example of comparison by pairs is given in Figure 6.20.

Figure 6.20: Example of a complete comparison by pairs of 4 treatments (adapted from Ashby, 1990)

Pair compared	Reasons for assessment	Score 1	Score 2	Score 3	Score 4
1 : 2	Coffee is less risky than vegetables.	+	–		
1 : 3	Coffee is more profitable than rice.	+		–	
1 : 4	Maize is difficult to market, price is low, only useful for home consumption.	+			–
2 : 3	Vegetables more risky than rice but more profitable when prices are good, although you can loose your shirt.		+	–	
2 : 4	Maize only for consumption		+		–
3 : 4	Rice not very profitable but necessary to grow it for daily consumption, and what remains goes for sale; maize not worth selling, is only eaten occasionally, not everyday like rice			+	–
Total Score And Rank Order	Positive (+)	3	2	1	0
	Negative (–)	0	–1	–2	–3

Note: – Options: 1 = coffee, 2 = vegetables, 3 = rice, 4 = maize
– The positive (+) or negative (-) scores are entered into the score matrix as follows: options 1 vs 2: 1 is scored a (+), therefore 2 is scored a (-); options 1 vs 3: 1 is scored a (+), therefore 3 scored a (-), etc. When the scoring is completed, the number of (+) signs can be summed to each option in the scoring matrix. This gives a rank order of the options. (The final assessment should however not be based on the mechanical addition of scores but on a thorough discussion of the advantages and disadvantages mentioned.)

Monitoring spontaneous adoption

The verbal assessment of trial options by farmers may not be the ultimate indicator for the quality of a potential innovation. However it is available soon after a trial season and therefore helps to adapt experimental designs. But a positive verbal assessment does not necessarily mean that a proposed innovation will eventually be adopted by farmers. The fact that an interview does not always reveal the real views of the farmer and the reasons for this were already highlighted in chapter 4.1.2. In addition, the experimental treatment which may appeal to farmers on the first glance may eventually not be feasible under real-life conditions (consider, for example, the nice car passing by on the road, which is really attractive – but nevertheless you can't afford to buy it).

A better proof of the quality of a potential innovation is the spontaneous adoption by farmers who were exposed to it. A means of investigating spontaneous adoption is a simple survey implemented in the season after the experiment was carried out.

It should explore
(a) quantitatively:
 – how many (or what percentage) of farmers exposed to the experiment adopted which of the trial options;
(b) qualitatively:
 – what are the reasons for adoption or non-adoption of trial options;
 – what kind of modifications were made to the original experimental treatments;
(c) whether adoption or non-adoption depends on specific target group characteristics of farmers.

Combining interview **and** observation in the field helps ensure that the information obtained reflects the true situation.

A quantitative assessment gives some indication of the extent to which a potential innovation would be adopted if it were promoted by the extension service. A high rate of spontaneous adoption suggests that a technology can be confidently promoted by the extension service. A high degree of rejection means that a trial innovation is not ready for extension recommendation.

In the latter case knowing the reasons for non – adoption and observing what modifications are made by farmers helps the researchers to improve the experimental options and to adapt the trial design.

Analysing farmers' assessment for statistical significant differences between treatments

Analysis of variance, T-test and mean comparison procedures as they were discussed in Chapter 6.2.2.1 are applicable only on measured (metric) figures, but not on ordinal numbers from farmers' ranking or rating of treatments. There are, however, very simple "nonparametric" tests available which can be used to analyse whether there are **significant differences between treatments with regard to their assessment by farmers.**

A very useful test is **Friedman 's test**, which is unfortunately not offered by every statistical computer programme, but very easily calculated by hand (see Annex 6.1). It is the nonparametric analog to the two-way randomized complete block (factorial) analysis of variance F-test. It is used to test differences among treatment means when the same set of treatments was assessed by all farmers involved in the assessment. It allows the comparison of more than 2 treatment means for a single variable (such as the overall assessment of treatments or any other defined assessment criterion) at a time. Scored (rated) as well as ranked data can be used.

The **Mann-Whitney-Test** can be applied on data from rating or ranking if there are only two treatments to be compared.

The **Wilcoxon Matched Pairs Test** is used to test differences between two **paired groups** of data, as they appear for example in the "pairwise comparison".

A matter of interest is sometimes to determine whether there is a **relationship between specific target group characteristics of farmers and their preference for a particular treatment**. This can be checked with an analysis of frequencies in a two way table (see Annex 6.1).

Cochran's Q-test is a modification of Friedmans's test which is applied when data exist only in two categories (for example "above average" and "below average", or "adopted" and "not-adopted"). It allows therefore to analyse data from adoption surveys on **differences between treatments with regard to adoption by farmers** (see Annex 6.1).

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Annex

Annex 6.1: Examples

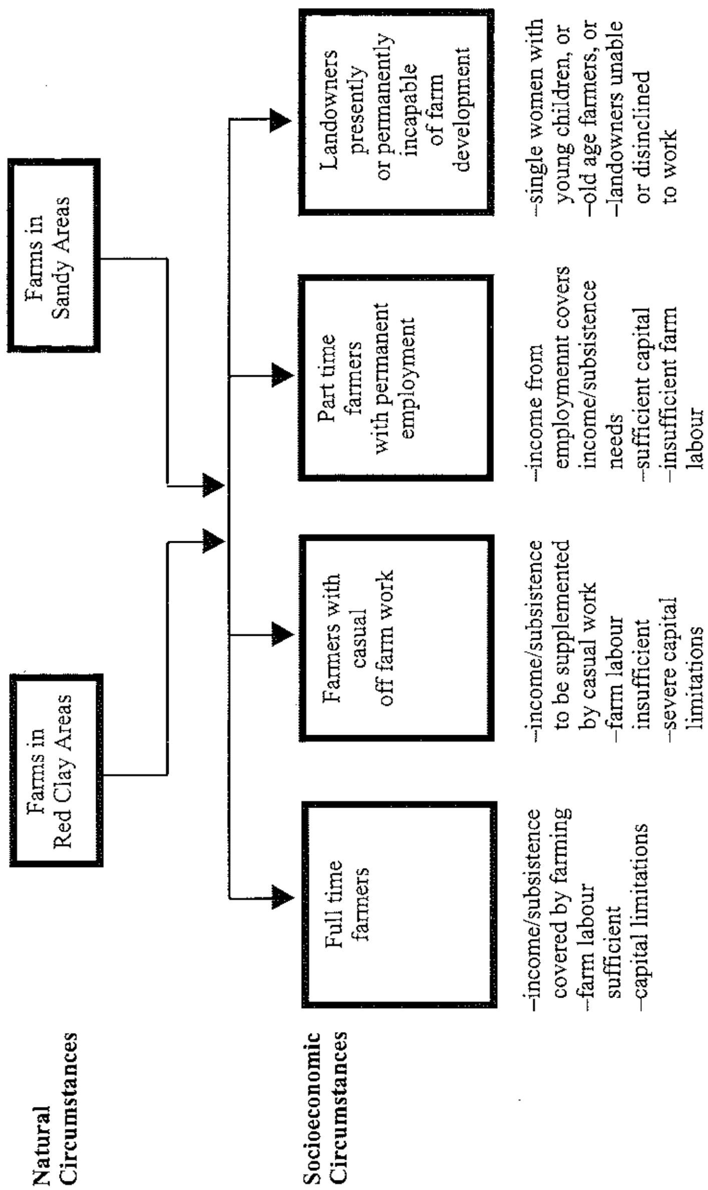
I Target grouping

Example 6.1 shows the **principal target group analysis** of a project. This kind of analysis tries to give an answer to the question "**which group of people is the project going to support?**". In this example the "part-time farmers with permanent employment" will not need the support of the project whereas the "landowners presently or permanently incapable of farm development" can hardly benefit from economically oriented development measures. The projects' target group should therefore be the "full time farmers" and the "farmers with casual off-farm work". This target group definition, of course, determines the groups of farmers to participate in research efforts.

This target grouping is not always specific enough with regard to the analysis of problems and potentials. It is sometimes only part of a target group which suffers from a specific problem or has a particular development potential. The analysis of problems and potentials calls therefore for a target group analysis specific to the identified problems and potentials. This warrants that

- the significance of a problem or potential is appropriately assessed and
- that relevant farmers are involved in the subsequent steps of the work.

Example 6.1: Project Specific Target Grouping (adapted from Neunfinger, Schmale and Werner, 1987)



A target group analysis specific to a problem or potential is shown in Example 6.2 The table shows the definition of problems and potentials identified (see Chapter 6.1.4) in the 2nd column, defines the groups of farmers affected by a problem or having a potential in the 3rd column and estimates the rate of farmers in these particular groups as compared to the total project target groups in column 4.

For most of the problems in the example, the group of farmers affected is simply defined by whether they grow a particular crop or not. Only those farmers who grow the crop in question and suffer from the identified problem should be involved in the identification and testing of possible solutions.

For some of the problems and potentials it is, however, a particular group of farmers that is involved: "Storage losses" (no.2), for example, is a problem which affects farmers in particular areas of the project (i.e. areas which are free of baboons and wild pigs and therefore allow the cultivation of maize on a larger scale). Working with farmers outside these areas would not be meaningful. Probably only farmers with access to water for supplementary irrigation would have the potential for vegetable production (no. 8), because sufficient labour would be available only from the second half of the rainy season into the dry season, i.e. at a period with an unreliable rainfall.

Example 6.2: Definition of problem or potential specific target groups (recommendation domains)

	Problem/potential	Group of farmers affected	Estimated % of project target groups
1	Interplanted cowpeas entangle cotton	Cotton/cowpea growers, in all project target groups	75
2	Storage losses of maize due to weevils	Maize growers with storable surplus, i.e. farmers in central project area (= area free of wildlife)	20
3	N & P deficiency of cotton and maize at sandy soil	Farmers in areas with sandy soil, in all project target groups	60
4	delayed 1st weeding affects annual crops	Farmers with labour shortage early in season; i.e. dominantly part time farmers with casual employment	50
5	Cashewnuts die for unidentified reason	Cashew growers, in all project target groups	95
6	Insect pests destruct cotton flowers and bolls	Cotton growers, in all project target groups	95
7	Citrus suffers from scab	Citrus growers, dominantly part time farmers with permanent employment	0
8	High demand for onion, green pepper, carrots,etc	Farmers with access to water for supplementary irrigation	25

Sometimes the problem specific target group analysis serves to exclude problems or potentials from further attention. In the example "citrus scab" (no.7), for instance, is a problem chiefly affecting "part-time farmers with permanent employment". This is a group of farmers outside of the projects main target group.

II Analysis of problems and potentials

(The following examples are based on discussions with farmers and field level extension workers at Lamu District / Kenya, 1991).

Example 6.3: Brainstorming
The brainstorming session results in an initial list of "problems and potentials".

Example 6.3: List of problems and potentials **(initial list)**

1 Interplanted cowpeas entangle cotton	**2** Storage of maize	**3** No fertilizer is applied	**4** Nutrient deficiency of cotton and maize on sandy soil
5 Delayed 1st weeding affects yields of annual crops	**6** Cashewnuts die for unidentified reason	**7** Insect pests destroy cotton flowers and bolls	**8** Input supply structure is weak
9 All crop residues are burnt	**10** Citrus suffers from scab	**11** High demand for vegetables = chance for diversification	**12** Cotton insecticides applied are not effective

This list contains mostly **problems.** The high demand for vegetables is not, from the farmers' point of view, a problem but it appears to offer a **potential for a diversification** of farming.

Example 6.4: Screening

The initial list of problems and potentials (→ Example 6.3) is **checked and streamlined**:

(–) **Are the statements relevant and understandable ?**

- The term "Storage of maize", for example, neither points at a problem nor at a potential. A more appropriate statement would be "Storage losses of maize due to weevils";
- the statement "No fertilizer applied" points at the absence of a solution and not at the problem. The problem should be clear before a solution can be considered. The problem here may be rather the "nutrient deficiency of cotton and maize".

– **Is it possible to formulate more specificly ?**
A statement on problems or potentials should be as specific as possible in order to show leverage points for potential options. For example it would be useful for statement (4) to name the nutrients that are deficient, or to list the vegetables being in high demand in statement (9).

– **Are there any repetitions ?**
The initial list often contains a number of statements which describe the same problem or potential in different words. In our example, statements (7) and (12) are related: (12) is a cause of (7). Also (9) appears to be a cause of (4). (9) and (12) can therefore be dropped from the final list.

– **Are all problems and opportunities within the reach of research measures ?**
The final list should contain only such problems and opportunities which can be addressed through the means of agricultural research. The initial list will always contain topics which are obviously not within the influence of research measures (like statement (8) in our example). Such topics are omitted in the final list, but not completely discarded: they may be of relevance for the identification of available options. A "weak input supply structure" is, for example, not the ideal precondition for options requiring purchased inputs. Furthermore it may be constructive to mention such problems and opportunities to other more relevant aid organizations.

The results of the screening process is the final list of problems and potentials as shown blow:

Example 6.4: List of problems and potentials **(final list)**

1 Interplanted cowpeas entangle cotton	2 Storage losses of maize due to weevils	3 N & P deficiency of cotton and maize on sandy soil
4 Delayed 1st weeding affects yields of annual crops	5 Cashewnuts die for unidentified reason	6 Insect pests destroy cotton flowers and bolls
7 Citrus suffers from scab	8 High demand for onion, green pepper, carrots and kales	

Example 6.5: Digging deeper

The **"problem tree"** overleaf **presents graphically** the interrelationship between problems and their causes. It shows that

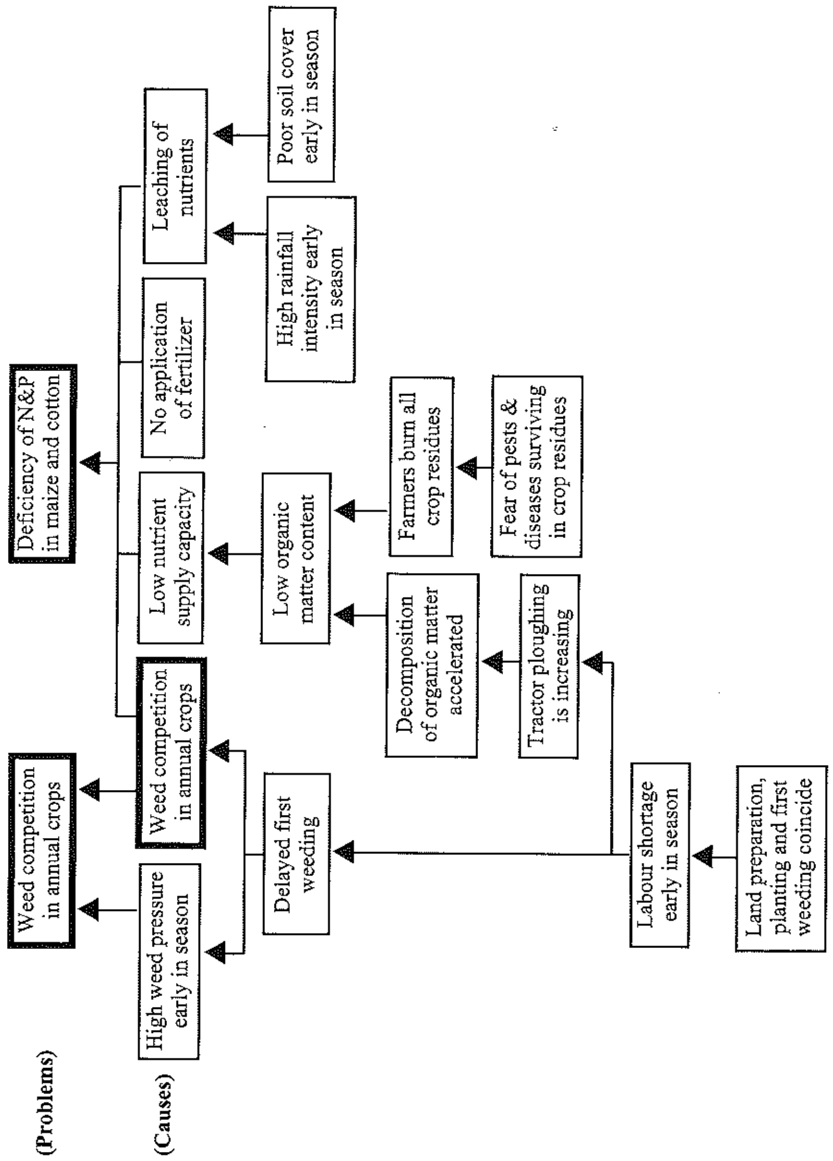
- there are usually several causes contributing to one problem; – a chain of causes may contribute to a problem;
- one single cause may contribute to several different problems (like "labour shortage" in the example);
- one problem may be a cause of another problem (as the "weed competition in the example).

The "problem tree" may pinpoint causes with a good chance of being solved through research efforts but it may also reveal factors that render a problem unsolvable with the given means.

The example of "N & P deficiency in maize and cotton" shows that there are sometimes several interlinked causes contributing to a problem. To solve the problem it will also require a number of different measures. A comprehensive analysis should be striven for in order to look into the right direction for possible options. Trying out fertilizer application alone would obviously not suffice in this case.

With farmers and field staff a **verbal summary** of the causes of stated problems is achieved more easily than the "problem tree". A verbal summary also facilitates the collection of additional information concerning identified potentials.

Example 6.5: "Problem tree"



Example 6.5: Verbal summary of additional information

High demand for vegetables is a chance for diversification, because
- the demand is unsatisfied after the end of long rains (July);
- there is a labour slack periode after weeding (June) until cotton harvest;
- the potential of periodically flooded depressions for recession cultivation is largely untapped.

Deficiencies of N & P in maize and cotton occur because of
- the low nutrient supply capacity of the soil, due to.....;
- the high weed competition early in the season, caused by...
-
-

III Analysis of variance and comparison of treatment means

Example 6.6: Analysis of variance and comparison of treatment means for a single factor experiment

Title: Cowpea varieties – Interplanting with cotton

Function: FACTOR
Data case no. 1 to 24
Without selection

Factorial ANOVA for the factors:
Variable 3 with values from 1 to 6
replicate 1-3
Variable 5 with values from 1 to 4
variety 1 = K80 2 = M66 3 = 577 4 = Local

Variable 7
cowpea yield kg/ha at 13% moisture

Grand Mean = 999.500 Grand Sum = 23988.000 Total Count = 24

TABLE OF MEANS

3 *	5 *	7	Total
1*	1*	1244.500	4978.000
2*	1*	1124.500	4498.000
3*	1*	1188.000	4752.000
4*	1*	730.500	2922.000
5*	1*	974.250	3897.000
6*	1*	735.250	2941.000
1*	1*	1311.833	7871.000
1*	2*	1202.333	7214.000
1*	3*	617.833	3707.000
1*	4*	866.000	5196.000

ANALYSIS OF VARIANCE TABLE

Code	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Rep	5	1016035.50	203207.100	2.77	.057
2	A	3	1813111.00	604370.333	8.25	.001
–3	Error	15	1098453.50	73230.233		

Coefficient of Variation = 27.07%

Example 6.6 shows the analysis of variance for a single factor experiment involving 6 farmers (variable 3) and 4 cowpea varieties (variable 5) as it is presented by MSTAT. The table of means presents in its **upper part** the mean cowpea yields **by farmer** and in the **lower part** the mean yields **by variety**.

The "Analysis of variance table" shows in line 2 that there are very highly significant treatment differences ("Prob = .001" is equivalent to the 0.1% level of significance). This experiment can not be analyzed for interactions between treatments and farmers, because there was no replication within farms.

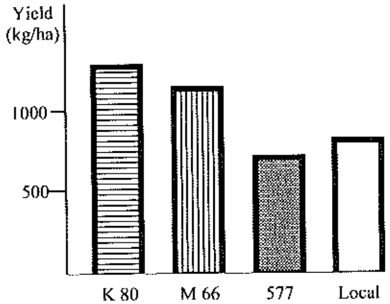
A pair comparison test, in this case "Duncans Multiple Range Test", was subsequently applied to analyze which treatment means differ from each other.

The results are presented in tabular form or as a bar chart. The letters behind the treatment means in the table denote significant differences between treatment means at the 5% level of significance: Any two means having a common letter are not significantly different at the chosen level of significance. The letters show K80 and M66 being significantly different from 577 and Local, whereas K80 and M66 as well as 577 and Local are not significantly different.

Table: Yield of cowpeas (kg/ha)
Cowpea variety trial, LKSS 1992

Variety	Yield (kg/ha)
K 80	1310 a
M 66	1200 a
577	620 b
Local	870 b
Mean	**1000**

Figure: Yield of cowpeas (kg/ha)
Cowpea variety trial, LKSS 1992



Example 6.7: Analysis of variance and comparison of treatment means for a full factorial experiment (wit non-significant interaction effects)

The following shows the table of means as it is produced by MSTAT and the analysis of variance table for a full factorial experiment on cotton and maize intercropping, involving two factors: Factor A being maize varieties with 2 factor levels (column 4 in the table of means) and factor B spatial arrangement of maize and cotton with 3 factor levels (column 5). 6 farmers participated in the experiment (column 3). Mean yields for **cotton** are shown in column 6.

TABLE OF MEANS, COTTON YIELD (kg/ha)

3*	4*	5*	6	Total
1*	1*	1*	1195.500	7173.000
2*	1*	1*	1228.167	7369.000
3*	1*	1*	495.667	2974.000
4*	1*	1*	1691.833	10151.000
5*	1*	1*	609.000	3654.000
6*	1*	1*	1274.500	7647.000
1*	1*	1*	847.056	15247.000
1*	2*	1*	1317.833	23721.000
1*	1*	1*	779.333	9352.000
1*	1*	2*	1175.833	14110.000
1*	1*	3*	1292.167	15506.000
1*	1*	1*	626.000	3756.000
1*	1*	2*	882.833	5297.000
1*	1*	3*	1032.333	6194.000
1*	2*	1*	932.667	5596.000
1*	2*	2*	1468.833	8813.000
1*	2*	3*	1552.000	9312.000

The first sector of the table of means presents the **mean cotton yields** by farmer, the second sector by maize varieties, the third sector by spatial arrangement and the fourth sector shows the mean cotton yields for all factor combination.

ANALYSIS OF VARIANCE TABLE

Code	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Rep	5	6064286.89	1212857.378	19.84	.000
2	A	1	1994685.44	1994685.444	32.63	.000
4	B	2	1734974.89	867487.444	14.19	.000
6	AB	2	127796.22	63898.111	1.05	.366
–7	Error	25	1528423.44	61136.938		

Coefficient of Variation= 22.84%

The analysis of variance table shows very highly significant treatment differences for factor A as well as for factor B. There was, however, no significant interaction effect between A and B. Spatial arrangement did, hence, not affect the results of maize varieties nor did maize varieties have an effect on the yields of the different spatial arrangements.

In this case the comparison of treatment means would be limited to the main factor effects, i.e. to the mean yields for the 2 maize varieties across all spatial arrangements and the mean yields of the spatial arrangements across both maize varieties. A pair comparison test will be required only for the 3 spatial arrangements, as the F-test already proves that the effects of the 2 maize varieties were significantly different. A comparison of all factor level combinations is not appropriate if the treatment interaction is not significant.

Without significant interaction effects also the presentation of results can be restricted to the main factor effects:

Table: Cotton Yield (kg/ha)
Maize variety x cotton spacing trial, LKSS 2

a) by maize variety	Cotton yield
Coast composite	850
Pwani hybrid	1320
b) by spatial arrangement	
Arrangement 1	780 b
Arrangement 2	1180 a
Farmers arrangement	1290 a

Example 6.8: Analysis of variance and comparison of treatment means for a full factorial experiment (with significant interaction effects)

The following analysis of variance table was computed for a full factorial experiment on cowpea interplanting into cotton, with 2 factors: factor A being cowpea varieties with 4 factor levels and factor B cowpea time of interplanting into cotton with 2 factor levels. 3 farmers participated in this experiment.

ANALYSIS OF VARIANCE TABLE

Code	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Rep	2	94782.33	47391.167	1.63	.231
2	A	3	780.46	260071.486	8.93	.001
4	B	1	8742.04	8742.042	64.18	.000
6	AB	3	1016454.46	338818.153	11.64	.000
-7	Error	14	407641.67	29117.262		

Coefficient of Variation = 31.94 %

The ANOVA-table shows very highly significant treatment differences for factors A and B as well as very highly significant **interaction effects between factors**. The comparison of means for the main factor effects can be misleading if the interaction effects are significant. Instead the comparison of means is done for the **factor level combinations**. A suitable tabular representation of results would be a two way table:

Table: Yield of cowpeas (kg/ha) interplanted with cotton by cowpea variety and time of interplanting

Cowpea Variety	Time of cowpea interplanting	
	Same time as cotton	Farmers Time
K 80	1070 ab	290 c
M 66	1160 a	210 c
577	840 b	220 c
Farmers'	170 c	310 c

Note: A mean comparison of all possible treatment means would not be appropriate. Only **pairs of means within the same row or within the same column** are being compared.

Example 6.9: Analysis of variance and comparison of treatment means for an experiment with location (site) as an experimental variable

The following analysis of variance table was calculated for a cowpea variety trial including four cowpea varieties. The trial was carried out at two villages with three farmers per village. "Location" (or village) was included as experimental variable in the analysis of variance.

ANALYSIS OF VARIANCE TABLE

Code	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Location	1	831792.67	831792.667	18.06	.013
2	R(L)	4	184242.83	46060.708		
4	A	3	1813111.00	604370.333	18.02	.000
6	LA	3	695983.00	231994.333	6.92	.005
-7	Error	12	402470.50	33539.208		

Coefficient of Variation= 18.32%

The ANOVA-table shows significant treatment differences. It also indicates a significant **interaction effects between treatments and locations** (varieties K80 and 577 responded strongly to the different environments, the other varieties did not).

The results are presented in a two-way table similar to that of the full factorial experiment. Pair comparisons are again appropriate only for values within the same row or within the same column.

Table: Yield of cowpeas (kg/ha) interplanted with cotton by cowpea variety and location

Cowpea Variety	Trial Location	
	Mpeketoni	Hindi
K 80	1560 a	1090 bc
M 66	1240 ab	1140 bc
577	1060 bc	180 d
Farmers	890 bc	840 c

The significant interaction effects between varieties and locations means that the varieties behaved differently at the different locations. In a subsequent step the factors need to be identified which contribute to the interaction between varieties and locations.

Note: Procedures and interpretation for analysis of variance across villages (or locations), farmers or seasons follow the same pattern.

IV Nonparametric tests to determine differences with regard to farmers assessment of experimental treatments

Example 6.10: Friedman's test

Problem: Four treatments were rated or ranked by ten farmers. Do the treatments differ from each other according to their scores?

The table below shows the overall ranking of four cowpea varieties carried out by ten farmers. Friedman's test analyses whether differences occur between treatments concerning the scores given.

Table: Overall ranking of four cowpea varieties by ten farmers (Rank 1 = best, rank 4 = worst)

Farmers	Treatment			
	K 80	M 66	577	Farmers
1	1	2	4	3
2	2	3	4	1
3	1	2	3	4
4	2	1	4	3
5	2	4	1	3
6	1	2	4	3
7	2	1	3	4
8	1	3	4	2
9	3	1	2	4
10	1	2	4	3
Rt	16	21	33	30
Rt^2	256	441	1089	900
Median	1.5	2	4	3

The test value X^2 is calculated as follows:

$$X^2 = \left(\frac{12}{k \cdot n \cdot (k+1)} \cdot \sum Rt^2\right) - 3 \cdot n \cdot (k+1)$$

k = *number of treatments*

n = *number of farmers*

Rt = *Sum of scores by treatment*

Therefore:

$$X^2 = \left(\frac{12}{4 \cdot 10 \cdot (4+1)} \cdot (16^2 + 21^2 + 33^2 + 30^2)\right) - 3 \cdot 10 \cdot (4+1)$$

$$\Rightarrow X^2 = 11.16$$

X^2 is compared with the tabular Chi-square value with k-1 = 3 degrees of freedom. Chi-square is 7.81 at p=0.05. X is larger than the tabular Chi-square, therefore it can be concluded that there are significant differences between the varieties with regard to their ranking by farmers.

When values to be analysed result from a rating using a defined rating scale or from measurements, they have to be transformed to ranks in order to calculate Friedman's test value. This ranking is done by giving the smallest value rank 1, next highest value rank 2 and so on. Scores with equal value get an average rank.

Note: In this example the number of farmers was only ten in order to make the calculation transparent. ten farmers is of course to little for a representative assessment. 30–50 representative farmers would be more appropriate (see also Chapter 5.2.6.1).

If Friedman's test yields a significant test value, multiple comparisons of treatments can be carried out for instance with the help of the Wilcoxon-Wilcox test.

Example 6.11: Q-test

Cochran's Q-test is a special case of Friedman's test configuration when data exist only in two categories (dichotomized data: yes-no, adopted-not adopted etc.). This is for instance the case when individuals get confronted with a number of treatments and the presence or absence of some attribute is observed (for instance accept – refuse).

Problem: Are treatments differently adopted by farmers ?

The following table shows the results of an adoption study on three cowpea varieties done with ten farmers. If a treatment was adopted by a farmer it is marked with a "+" sign, if not a "-" sign is used.

Table: Adoption and non-adoption of three cowpea varieties by ten farmers one season after trial implementation ("+" = adopted, "-" = not adopted)

Farmer	Treatment			Li	Li^2
	K 80	M 66	577		
1	+	+	–	2	4
2	+	–	–	1	1
3	+	+	–	2	4
4	+	+	–	2	4
5	+	–	+	2	4
6	+	+	–	2	4
7	+	+	+	3	9
8	+	–	–	1	1
9	–	+	+	2	4
10	+	+	–	2	4
Tj (= no. adopted)	9	7	3	$\sum Li = 19$	$\sum Li^2 = 39$
% adopted	90	70	30		

The test value Q is calculated as follows:

$$Q = \frac{(k-1)\cdot(k\cdot\Sigma Tj^2-(\Sigma Tj^2)}{k\cdot\Sigma Li-\Sigma Li^2}$$

k = *number of treatments*

n = *number of farmers*

Tj = *number of positive reactions per variety (how many farmers adopted a particular variety)*

Li = *number of positive reactions per farmer (how many varieties were adopted by a particular farmer)*

(*n · k should be* >23!)

Therefore:

$$Q = \frac{(3-1)\cdot(3\cdot 139-361)}{(3\cdot 19)-39} = \frac{112}{18}$$

$$=> Q = 6.22$$

Q is compared with the tabular Chi-square value with k-1 = 2 degrees of freedom. Chi-square is 5.99 at p=0.05. Q is larger than the tabular Chi-square, therefore it can be concluded that there are significant differences between the varieties with regard to their adoption by farmers.

The Q-test is also suitable to **test changes in adoption habits**. It could be of interest to test if the adoption rate concerning a specific treatment changes over time.

If the treatment is accepted by a farmer a "+" sign is given,
if the treatment is not accepted by the farmer a "-" sign is given.

Table:

Farmer	Year					
	1	2	3	4	....	m
1	+	+	+	–	....	
2	+	–	–	–		
3	+	+	..			
. . .						
N	..	..	..	..	....	

Example 6.12: Analysis of frequencies in two way tables (independent samples)

Problem: Is there a relationship between specific target group characteristics (such as affiliation to a defined income, age or ethnic group) **and preference for a particular treatment** (only the best ranked treatment is counted) ?

This problem can be solved with the Chi-square statistics.

Income groupe	Treatment				
	1	2	3	....	Ri
1	f11	f12	f13		R1
2	...	...	...		R2
3	...	...	...		...
⋮			fij		
Cj	C1	C2	C3	....	N

Ri	=	*Row totals*
Cj	=	*Column totals*
N	=	*Sample size (total number of observations)*
fij	=	*observed cell frequencies (i.e. f 11 = number of people in income group who prefer treatment 1 ...)*

The expected frequencies (eij) have to be calculated for every cell:

$$eij = Ri \cdot Cj \cdot \frac{1}{N}$$

$$\text{Ci-square test value} = \Sigma \frac{(fij - eij)^2}{eij}$$

with $(c-1)\cdot(r-1)$ degrees of freedom.

The test value is compared with the respective value of the Chi-square distribution.

Annex 6.2: Brief software overview (by H.G. Schön, STATITCF by W. Graf)

MSTAT

MSTAT-C is an integrated microcomputer program specifically designed for agricultural research. It is intended to help the researcher through all stages of experimentation.

MSTAT is a menue driven program which generates experimental designs, manages and transforms data and analyzes trials from both a biological and an economical perspective. It provides applications like trial design, field books, descriptive statistics, cross tabulation, t-test, ANOVA, nonorthogonal analysis of variance, range tests, nonparametric test, correlation and regression, economics, etc. The economics subprogram follows the procedures described in the CIMMYT manual "From Economic Data to Farmer Recommendations" (see Literature). The graphical facilities of MSTAT are not as powerful as those of other programmes described.

MSTAT imports and exports ASCII files. Data can be entered also through the integrated spreadsheet. MSTAT is easily installed and relatively user friendly.

MSTAT requires an IBM compatible PC with a minimum of 512 K RAM, MS-DOS and a hard disk. MSTAT is very reasonably priced.

Dialogue language: english.

Distributor: Michigan State University, MSTAT/Crop and Soil Sciences, A87 Plant and Sciences, East Lansing, Michigan 48824, USA

SOLO

SOLO Version 4.0 provides a wide range of statistics from descriptive to multivariate (descriptive statistics, cross tabulation, t-tests, ANOVA, GLM, ANCOVA, linear and nonlinear, simple and multiple regression, nonparametrics etc.) as well as an array of data management and transformation capabilities.

SOLO creates and prints a wide range of statistical graphics with strong exploratory features and presentation graphics in reasonably good quality. The graphics options interface thoroughly with the statistical portion of the package. The package is fully menue-driven and uses "fill in the panel" technique. The panels allow to quickly define the options to customize the analysis. With the panels you are presented with all the options at once. One can move around with the cursor to the fields and a "help" message with all the options for that field becomes visible.

SOLO allows to store up to 500 variables and 30 observations on a data base. Formatted in a spreadsheet fashion, the editor enables easy data management. Data can be imported and exported (ASCII-format and important spreadsheet formats). SOLO does not offer any capabilities to conduct specific economic analyses. Data processing of voluminous data sets (1000 records) gets increasingly slow when complex procedures are used.

The program is easily installed. SOLO requires an IBM PC or compatible, with 512 K of RAM, about 4 MB hard disk space and MS-DOS. SOLO is available in various dialogue languages and very reasonably priced.

Distributors:BMDP Statistical Software, 1440 Sepulveda Blvd., Los Angeles, CA 90025, U.S.A.

in Europe: Cork Technology Park, Model Farm Road, Cork, Ireland

SPSS/PC+

SPSS/PC+ derived from the main-frame and is a modular, interactive program. The program contains several modules: Base, Statistics, Advanced Statistics, Tables, Trends, Categories, Graphics, Mapping and Data Entry II. The modules Graphics and Mapping of the PC-version are interfaces; the module Graphics needs Harvard Graphics or MS-Chart as enhancement, the module Mapping works together with MapInfo or PC-MAP. SPSS/PC+ has strong statistical capabilities, a very good handling of missing data, batch capabilities and can process large data sets in a speedy way. On the other hand SPSS/PC+ demands a capable hardware configuration, especially a lot of hard disk space.

SPSS/PC+ is available for IBM PC's or compatibles and APPLE Macintosh. Besides the MS-DOS version an SPSS for WINDOWS version is meanwile offered. SPSS/PC+ is available in various dialogue languages. Since it is a very powerfull statistical package it is quite expensive.

Distributor: SPSS Inc., 444 N. Michigan Avenue, Chicago, Illinois 60611 U.S.A.

SYSTAT/SYGRAPH

SYSTAT/SYGRAPH version 5 is a comprehensive statistics, graphics, and data management package for IBM/compatible (MS-DOS and WINDOWS version) and Macintosh. This package offers a full range of univariate and multivariate statistical procedures and a great number of two- and three-dimensional graphics for scientific and statistical applications, including dynamic 3-D data plot spinning. SYSTAT is basically command driven, but offers a menue facility, which works quite slow.

Distributor: SYSTAT Inc. 0 Sherman #801, Evanston, Illinois 60-3793 U.S.A.

STATITCF

STATITCF is a microcomputer software designed specifically for agricultural research. It is fully menu driven and has an extensive help feature. It has therefore a high value for teaching purposes. It features cross tabulation, ANOVA, t-test, non-parametric statistics, mean separation tests, principal component analysis, analysis of time series, regression and multidimensional ANOVA.

STATITCF imports and exports ASCII, DBase^{3+}, Lotus and other DIF-files. Data can also be entered through the STATITCF-spreadsheet, but only 60 variables can be handled directly. The graphic feature is modest.

The programme requires an IBM compatible PC with DOS, 512 K RAM and 10 Megabite hard disk space. It is reasonably priced. It is available with french dialogue language only and widely used in francophone tropical countries.

Distributor: Institut Technique des Cereales et des Fourrages,
8,Av. du President Wilson, F-75116 Paris, France

Worksheet programs

Common Worksheet programs offer a wide range of spreadsheet functions , data base management possibilities and have powerfull presentation graphics abilities. Worksheet programs are very handy for preparing matrices for the analysis of trials and surveys. They offer, however, also basic statistical functions like mean, standard deviation, variance etc. and simple and multiple regression. The data can be presented in two- and three-dimensional graphics display. Popular displays used in descriptive statistics are available. Important transformations are offered. Quite a number of functions deal with cross-tabulation, but Chi-square statistics is not included. These packages are in general handy.

A key to statistical methods and to what different computer programmes can do

(I) Measurement Variables (normal Distributed)	Purpose	Method	Software (- Module)
1 variable 1 treatment	Examination of a single sample	Arithm. mean, Standard dev., Standard error, Confidence limits, Histogram	SOLO – Descr. Statistics SPSS, SYSTAT, MSTATC, STATITCF, EXCEL, LOTUS 123 etc.
1 variable 2 treatments	Independant variates	T-test	SOLO, MSTATC; STATITCF, SPSS, SYSTAT, MSTATC, EXEL, LOTUS 123
	Paired variates	Paired comparisons test	SOLO, MSTATC, SPSS, SYSTAT, STATITCF
1 variable ≥ 2 treatment	Single classification	one-way-ANOVA	SOLO – ANOVA – GLM ANOVA SPSS – ANOVA, MANOVA MSTATC, STATITCF, SYSTAT
	Block design and multi way classification	Multi-way ANOVA	SOLO – GLM ANOVA – ADVANCED SET SPSS – MANOVA MSTATC, SYSTAT, STATITCF
	Comparison among means	Mean separation procedures	SOLO, SPSS, SYSTAT, MSTATC, STATITCF
2 variables	Prediction of functional relationship	Regression statistics	SOLO – GRAPHICS MENUE – REGRESSION SPSS, STATICTCF, SYSTAT, MSTATC, EXCEL, LOTUS 123 etc.
	Association	Pearson's correlation coefficient	SOLO, SPSS, SYSTAT, MSTATC, STATITCF, EXCEL, LOTUS 123 etc.
≥ 3 variables	Prediction of functional relationship	Multiple regression	SOLO, SPSS, SYSTAT, MSTATC, STATITCF
	Association	Coefficient of multiple correlation, Coefficient of partial correlation	SOLO, SPSS, SYSTAT, MSTATC, STATITCF

(II) Ranked Variables (also Measurement Variables Without Normal Distribution)	Purpose	Method	Software (- Module)
1 variable 1 treatment	Examination of a single sample	Median	SOLO, SPSS, SYSTAT, MSTATC, EXCEL, LOTUS 123 etc.
		Box-and-Whisker plot	SOLO, SPSS, SYSTAT
		Frequency distr. and other diagrams	SOLO, SPSS, SYSTAT, MSTATC, STATITCF, EXCEL, LOTUS 123 etc.
1 variable 2 treatments	Independant variates	Mann-Whitney-Test	SOLO – NONPARAM. STAT., SPSS, SYSTAT, MSTATC
	Paired variates	Wilcoxon's signed ranks test	SOLO – NONPARAM. STAT., SPSS, SYSTAT
1 variable ≥ 2 treatment	Single classification	Kruskal-Wallis test, Nemenyi test	SOLO – NONPARAM. STAT., SPSS, SYSTAT
	Two way classification	Friedman's test	SOLO – NONPARAM. STAT., SPSS, SYSTAT
2 variables 1 treatment	Association	Coefficient of rank correlation	SOLO, SPSS, SYSTAT
≥ 3 variables 1 treatment	Association	Kendall's coefficient of concordance	STATITCF

(III) Attributes	Purpose	Method	Software (- Module)
1 variable 1 treatment	Examination of a single sample	Diagrams	SOLO – GRAPHICS MENUE, SYSTAT, STATITCF, EXCEL, LOTUS 123 etc.
1 variable ≥ 2 treatments	Single classification	Chi-square statistics	SOLO, SPSS, SYSTAT, MSTATC, STATITCF
	Two way or multi-way classification	Log-linear models, Q-test, McNemar-test	SOLO, SPSS, SYSTAT, MSTATC
2 variables	Association	Chi-square statistics, G-test	SOLO, SPSS, SYSTAT, MSTATC, STATITCF
≥ 3 variables	Association	Log-linear models	SOLO, SPSS, SYSTAT