Development of a Computer Based Decision Support System for Introducing No-Till Technology

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My life has been so blessed with many wonderful friends. I have a special love for those who continued to ask me about my work. Without your interest and encouragement, it might have been very difficult. A dedication to me and my other brothers and sister of a book by my elder brother proved that he had faith in me. I thank each of you.

Abstract

No-Till cropping systems have evolved rapidly since the early 1960s and have attracted attention world-wide. The difficulty of transferring new technologies is also well established. The selection of a tillage system is a difficult management decision with long term implications. Specific constraints impede its implementation. No-Till has the potential to conserve soil and energy as well as to sustain the agricultural ecosystem, yet some soil types have high cultivation requirements to maintain optimum soil structure. Climatic factors, such as level of precipitation, can influence both plant response to soil compaction and the timing of crop establishment. Furthermore, biological constraints such as plant diseases or specific weed species can become controlling factors governing the successful adoption of No-Till. The use of an expert system is considered the best way to derive the researchers' knowledge and aid the process of choosing an appropriate tillage technique.

The No-Till Expert (NOTE) System is designed to aid farmers and extension workers in their decision-making process for promoting No-Till. A prototype expert system has been developed and initially run in Pakistan under the rice-wheat and cotton-wheat rotation. A model for popularizing No-Till technology is also proposed. Over-drilling pasture, and crop establishment data from New Zealand conditions has been incorporated for possible use of this expert system in developed agriculture.

The following technical, social, and economic input parameters have been incorporated in the NOTE. Users are required to input information concerning each parameters (guidance in selecting values is provided).

Technical: Soil texture, soil slope, crop rotation, weed and pest management, straw residue management, seeding technology, and soil moisture condition around seed micro-environment at the time of planting.

Social: The ability to carry out a particular operation correctly determines the farmer's ability to manage No-Till successfully. Therefore, the literacy level, use of knowledge for correct and timely operations is also considered under the social aspects in this study.

Economic: If the cost of productions, and productivity is not likely to vary positively with the change in tillage technique, it would be difficult for extension workers to convince farmers to change their existing practices. Thus, the economic aspects of No-Till were also considered.

Environmental, local legislation, residue handling, use of chemicals, and its impact on ground water contamination were the other key factors that were considered while designing NOTE. However, these were not incorporated in the final design of NOTE because of lack of the available quantitative data.

NOTE interactively considers the above parameters and makes appropriate recommendations as to the acceptance/rejection of No-Till. Based on the wide range of studies on above subjects, NOTE out-rightly rejects No-Till under the following conditions:

1. If the area is affected by rice stem borer, and the requisite pesticides are not available under Pakistani condition.

2. If the soil texture is heavy and not well drained.

3. If the requisite weed control chemicals are not available.

4. For growing cereal after pasture, as sowing of an intermediate crop is recommended under New Zealand situation because of likely transfer of Argentine

stem weevil. However, if farmer could afford to apply some appropriate pesticides, No-Till could be considered.

5. If farmer does not have access to a No-Till drill.

NOTE, however, has in-built facilities for future upgrading. Such upgrading would be required to account for more specific climatic conditions, locations, and crops.

A User's Guide has also been developed to assist end-users to use this decision support package.

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Development of a Computer Based Decision Support System for Introducing No-Till Technology

Chapter-1 INTRODUCTION AND OBJECTIVES

1.0 The Scope and Need for an Expert System in Soil Tillage

Farmers' need for modem information technology depends on the sophistication of their decision-making and on their willingness to collect and record the data needed for the decision making process (Van Den Ban and Hawkins, 1988). As farming operations have become larger and more complex, the need for timely information has also become more important. Therefore, computers have become important tools in farm management activities (Pasqual, 1994), thus providing a new medium for extension workers to transfer agricultural knowledge and technology, and creating new opportunities to increase the efficiency of disseminating new agricultural techniques.

Computers can play two important roles in agriculture: in management of agricultural activities, and in extension activities. For example, with fast changing agricultural technologies, selecting the appropriate technique at the right time is a crucial task that can affect long term productivity on farms. A wrong decision can be costly and risky. To avoid disappointment, the farm management decision should therefore be based on comprehensive and recent knowledge. With the help of computer based Expert Systems (ES), such decision making can be made easier. Similarly, extension agents can play an active role (with more confidence) in introducing new ideas through computer models.

Expert Systems are developed by computer scientists in collaboration with experts in a particular field. These are designed to embody the knowledge of an expert, and then generate advice based on prevailing conditions, through the application of reasoning in a manner akin to a human expert (Waterman, 1986). Recently, computer based expert systems have become common in agriculture for assisting extension agents and farmers in glass house operations, pig farming, dairy farming, selection of seed drills, and soil analysis (Plant and Stone, 1991). For instance, by using an ES on tillage, a farmer may learn what a tillage system does, how it works, and what it produces efficiently. The ES may also help in explaining to the user why it works, why it may not work, and to be able to change it so it may work (Triplett and Sprague 1986).

The Global 2000 Report (Barney, 1980) indicated that even allowing for the beneficial effects of improved technology, the world's population by the year 2000 may be within a few generations of reaching the planet's carrying capacity. Projections place the population in excess of 6.3 billion in the year 2000, an increase of 1.7% per year from 4.1 billion in 1975. Projecting further, approximately 10.8 billion people can be expected to need a productive agricultural system by 2025. It is documented in the same report that only 4 of 12 groups of nations produced grain in excess of per capita consumption in 1970 and this number declined to 3 in 1975. The projected grain deficit in the less-developed countries by the year 2000 was placed at 14.6 kilograms per capita, up from 10.8 kilograms in 1970 (loc. cit.). With this population trend, production must be accelerated if civilizations are to prosper.

With the exception of Japan, the principal agricultural products in most developed countries are livestock rather than crops. Thus, most of the land is used for their support, either as cultivated grassland or for the growth of fodder crops. The future of agriculture in developed countries depends on a number of developments outside agriculture as well as changes within agriculture itself. These changes include the availability and cost of fuels; trends in agricultural productivity; demographic trends; the demand for different kinds of food; policies on food-aid; assessments of the environmental effects on modern farming; and changes in lifestyle as a consequence of technological change. In general, due to higher yields of crops in the developed countries, they are already major exporters of food crops to developing countries. Lack of financial resources in the developing countries is now limiting the possibility of buying the surplus produce from the developed countries. Therefore, the situation demands an improvement in the agricultural techniques used in developing countries currently so that these countries may become self-sufficient in at least the main food crops. There have already been few good examples. For instance, in Egypt the cotton and wheat crops traditionally have yields at par with the yields in developed countries agriculture. Similarly, in China commendable improvement in rice yield has been reported.

The greatest opportunity for increasing food supplies lies in restoring productivity where it has been lost (Lal, 1991). Triplett and Sprague (1986) reported two major problems related to agricultural productions: deterioration of the soil and efficiency in the use of available water. They observed that conservation of soil and water resources alone was not enough and a system of recharging them was necessary on a continued basis to regain the productive ability.

Tillage is one component in which a change could mean improvement in both water use and nutrient use efficiency. It forms a subsystem of soil management, directly influencing the soil system's performance or productivity, mainly through crop establishment, modification of soil structure, incorporation of crop residues, and weed control (Carter, 1994). Tillage is also needed to cover surface residues and provide a cleaner soil surface environment for seedlings emergence. After harvesting, sometimes, a heavy rainfall can create unfavourable field conditions for the next crop, making tillage necessary. Levelling or shaping of a field by ploughing and discing is also one of the reasons for undertaking tillage (Phillips and Phillips, 1984).

Unfortunately, excessive tillage causes soil erosion and degrades soil structure. Triplett and Sprague (1986) observed that the introduction of herbicides after World War II provided a new tool to reduce excessive tillage. During that time chemical energy was substituted for tractor energy to reduce competition from weeds during and after seedling establishment. Conservation tillage was the result of research aimed at reducing tillage operations, avoiding runoff, conserving energy and soil, and improving surface water quality. Lately, these tillage systems have become common in many parts of the USA and other countries. On the other hand the new environment arising from major reductions in tillage not only provided new solutions to soil erosion and maintenance of soil structure, they also created new problems and opportunities to the farming community. New problems included the need for a higher level of management under reduced tillage techniques, while opportunities included flexibility in planting and harvesting, increased land use, and lower equipment requirement (Phillips and Phillips, 1984). The choice of a suitable tillage system depends on soil characteristics, the nature of the crop to be grown, the agro-ecological environment, and the socio-economic status of the farming community. Selection of a tillage system is a complicated management decision with long term implications. The situation seems to be further aggravated when it is known that solution to any farm management problem varies between regions, farms, and from season to season. This is because temperature and moisture conditions often affect land capability, yields, and other agricultural management activities. Lal (1979) observed that no single tillage system could be used for all soils, crops and agro-ecological environments. According to this observation, tillage systems were locale specific, and should be developed for all conditions to solve the specific problems of soil and water management, cropping systems and energy needs of the region. Thus, regional imbalances as well as differences within regions, are important aspects to be considered.

The use of an ES is considered the best way to derive the researcher's knowledge and aid the process of choosing an appropriate tillage technique. The most common expert systems are rule-based expert systems in which the experience and knowledge of a human expert is captured in the form of **IF-THEN** rules and facts, and used to solve problems. When the data accumulated for a particular problem match the conditions stated in the **IF** part of the rule, the statements in the **THEN** part of the rule are executed. The program is structured in such a way that through an interactive process, a general practitioner, or layperson can be guided through the steps required to solve a complex problem. These expert systems operate in much the same way as conversation between an expert and a layperson in that the system prompts the user for information and objectives of the study. Should the user be unfamiliar with any requested information, the ES provides explanations of what is required or recommends a course of action.

1.1 Objectives

Although, attempts have been made to design an expert system for developing specifications for soil engaging components on conservation tillage planters, drills and seeders, there has not been any reported expert system for selecting a specific tillage method.

The objective of this study was to develop a knowledge-based computer system to aid solving the problem of choosing appropriate tillage technology for non-experts. Factors influencing crop establishment were to be identified, and incorporated in the proposed expert system (ES). The ES was to include factors which influenced farmers' decision of either choosing or rejecting No-Till.

Based on this study, a model for awareness-building and introduction of No-Till technology was to be suggested.

It was envisaged that this study would contribute to non-expert farming communities in following ways:

1. It would provide economical, yet comprehensive advice on accepting or rejecting No-Till under given conditions.

2. It would disseminate knowledge regarding crop establishment.

3. It would identify why it rejected the use of No-Till; this which would help the extension agencies to ascertain how to remove the constraints associated with the adoption of the No-Till.

4. This would therefore guide research aimed towards eliminating both the short and long term barriers to the introduction of No-Till.

Chapter-2 Computers in Agriculture

2.0 Background

The basics of agriculture have not changed since humankind first prepared the ground, planted seeds, cared for crops, harvested and ultimately consumed the produce (Anon., 1985). In recent time science has played a key role in producing better crops and livestock and farmers have not been slow to accept the fruits of scientific and technological endeavour (Hardaker, 1979). Scientific discoveries have led to better crop fertilization, improved weed and insect control, and improved crop varieties. These discoveries, have influenced changes in the structure of agricultural production system (Edwards, 1989). New production areas have been developed and production capacities have been reported to exceed the demand for products produced.

Plant and Stone (1991) stated that meeting the challenges of the current development in agricultural decision making must be based on up-to-date knowledge. Currently, as the farming operations have become larger and more complex, timely information and decisions have become crucial. There is a bewildering range of available options from which farmers have to choose for critical management decisions in order to make their farming profitable. Various management options can affect long term productivity of a farm which can be both costly and risky for farmers. For example, management of crops or livestock is a problem characterized by an unusually high level of uncertainty in almost all decisions. The weather, the level of pest infestation, the price of the crop or livestock, and the availability of nutrients are known to have very imprecise values at times. Farmers have to decide which tillage system will be more suitable for their particular farming conditions, what kind of pesticide or fertilizer to choose for specific weeds. Similarly, herbicide effectiveness can also be reduced by factors such as climate, soil type, weed tolerance, crop residues, and presence of pests and diseases. Poorly timed decisions on what herbicide to use, and when, may depress yields to an extent that the cost of using a herbicide may not be justified; or poor timing of chemical use may mean that satisfactory weed control is not obtained. Therefore, it is anticipated that collecting the latest information on the above mentioned factors can help in making correct decisions for improving farming income.

Agriculture, like other industries, has moved into the computer age with information technology being increasingly applied and its development appearing to offer unlimited opportunities (Xin *et al,* 1997; Blokker, 1984). Computers have become important tools in farm management activities (Pasqual, 1994) by providing a new medium for extension workers to transfer agricultural knowledge and technology, and by creating opportunities to increase the efficiency of introducing new agricultural techniques. The past decade has seen the emergence of `expert system' (ES) computer programs designed to embody the knowledge of an expert in a field, to generate advice and solve problems (Waterman, 1986). For example, McKinion and Lemmon, 1985; Stone *et al,* (1986) reported that due to advances in ES technology and its application to complex agricultural problems, an ES approach may provide extension workers with ready access to weed control advice. Because of the speed and capacity of the computer, farmers, agri-business people, and extension workers are now able to access, sort and process research information. Through computers it has become possible for scientists in different disciplines to pool their knowledge in appropriate simulation models and to scrutinize the impact of different events. Edwards (1989) predicted that the future of knowledge-based decision support ES and the increasing use of information to ensure the most efficient production and marketing would depend on the willingness to use and support these new technology products. Thus, the challenges in tomorrow's agriculture will require best expertise available with the computer expert systems offering one such opportunity to remain competitive and profitable in the changing global agricultural environment.

2.1 Use of Computers in Agriculture

The farmers' need for modern information technology depends on the sophistication of their decision-making and their willingness to collect and record the data needed for the decision-making process (Van Den Ban and Hawkins, 1988). The move towards expert systems is an important development in information technology as these help farmers to choose the better option from a wider range of possible alternatives, by processing data from a large number of variables and according to certain validated rules developed by the experts. Van Den Ban and Hawkins (1988) state that there is no doubt that expert systems apply the decision rules more consistently and process the relevant data more effectively than the farmer can. They further claim that since a decision retrieved from an ES scrutinizes through a higher level of agricultural research and relevant data it may have positive impact on farm income.

Frequently confronted problems in agricultural engineering include obstacles with livestock, tillage machinery, or the handling of crop residues. For example, poor machinery management will not only influence productivity, but unwanted delays and repairs could erode potential profits that might have been expected under various tillage systems. An example of such a problem was quoted by Conacher and Jeanette (1986) where it was reported that in Western Australia the Kondinin and Districts Farm Improvement Group found a high level of dissatisfaction over farm machinery performance. This report also indicated some common problems as: inability of machines to handle crop stubble; unsuitability of machines to local conditions; poor seed depth control; high levels of damage and breakages; poor back-up service and lengthy delays for repairs; and wide performance variations between the machines. Computer based expert systems containing data, and their usage at appropriate time, can help in solving such problems by retrieving and using the expert's knowledge from its ES data base.

Claustriaux (1992) studied various categories of farmers in South Belgium who wished to use computer on farms (Table 1).

Table 1 indicates that farmers having larger area (> 30 ha) or livestock (≥ 50 cattle) wished to use computers. Most of the farmers wished to use computers in assisting them in accountancy. The farmers' age influenced the adoption of computers on their farms, as 67% farmers above ≥ 50 years showed no interest to become computer literate.

While studying the literature two terms i.e.: "decision support system" and "expert system" are often used snonymously (Gonzalez and Dankel, 1993) the term **expert system (ES)** will be used for this review.

Table 1 **Data showing Farmers's interest to use computers on their farms in Southern parts of Belgium.**

Parameters	Computerised farmers (5.6%)	Farmers wishing to become computerised (46.3%)	Farmers not wishing to become computerised (48.1%)
Farm surface area > 30 ha	69%	78%	49%
≥ 50 cattle	79%	67%	51%
Mean age (yrs of farmer)	39	41	51
≥ 50 yrs old	29%	25%	67%
Education ≥ secondary	55%	54%	24%
Accountancy aids	85%	83%	55%
Robotics	21%	8%	1%

2.2 Computer expert systems

2.2.1 Decision Support Systems (DSS)

Little (1970) defined DSS as "model-based set of procedures for processing data and judgements to assist a manager in his decision making". He argues that in order to be successful, such systems must be (1) simple, (2) robust, (3) easy to control, (4) adaptive, (5) complete on important issues, and (6) easy to communicate with.

Ginzberg *et al,* (1982) reported Gorry and Morton (1971) identifying DSS as systems to support managerial decision makers in unstructured or semi-structured decision situations. Two key concepts in this definition are ***support*** and ***unstructured***; which indicate these systems are meant to be an adjunct to the decision makers. Thus they are to be used to extend decision makers capabilities and not to replace their judgement. DSS are also aimed at supporting those decisions where judgement was required but due to complications the decisions were turned over to the computers for an opinion. Keen and Morton (1978) identified three purposes of a DSS:

1. To assist managers in their decision processes in semi-structured tasks. They suggest that this could be done by providing interactive access to stored data and decision models with a convenient user interface.

2. To support, rather than replace, managerial judgement. They suggest that the interactive capabilities and convenient user interfaces provided by DSS allow managers to exert more control over the application of technology to decision making than was previously available.

3. To improve the effectiveness of decision making rather than its efficiency. This was done by extending the range and capabilities of manager's decision processes, - for example, by means of computer data base that can rapidly analyse and solve the problem.

2.2.2 Expert Systems

Since the mid-1970's, a variety of expert systems have emerged on the market and have been successfully applied in many fields such as medical diagnosis, electronic circuit analysis, computer configuration, mineral exploration, air-traffic control, photo interpretation, automatic programming, mathematics, physics, chemistry, and genetic engineering (Forsyth, 1986). Dendral (1965-70), MYCIN (mid 1970), Prospector (Late

1970s), and XCON (early 1980s) were the prominent expert systems till the early eighties. Recent trends in computer science have enabled computers to handle difficult tasks; for example, the simulation of expert's reasoning, or dealing with uncertainty, therefore the definition of ES evolved with the passage of time. Lately expert systems are said to have the capability of grasping fundamental domain principles to solve complex problems and to interact intelligibly with the user (Pasqual, 1994).

Bramer (1984) defined an ES as a computing system which embodies organized knowledge concerning some specific area of human expertise, sufficient to perform as a skilful and cost-effective consultant. Huggins *et al,* (1986) described expert systems as "computer programs designed to emulate the logic and reasoning processes human experts would use to solve a problem in their field of expertise." Expert systems function primarily on the concept of "IF_____THEN_____" rules. Expert systems are computer applications which embody some non-algorithmic expertise for solving certain types of problems, therefore, they are used in diagnostic applications servicing both people and machinery. They also make financial planning decisions, configure computers, monitor real time systems, underwrite insurance policies, and perform many other services which previously required human expertise. Lucas and Gaag (1991) observe that expert systems are used to solve real-life problems which do not have a pre-defined solution to be found in the relevant literature. Currently, research in expert systems aims at building systems which can handle incomplete and uncertain information and perform as well as a human expert.

No-Till Expert (NOTE) System designed in this study requires the user to input information on various parameters influencing the decision-making process on either choosing or rejecting No-Till. Guidance in selecting appropriate values is provided and these values are placed in the given dialogue boxes. Once the values are entered, a recommendation is made. However, when incomplete information is provided and with only a few input values entered, NOTE still makes a recommendation, but reminds the user to enter more information in the dialogue boxes for a better recommendation.

2.3 Use of Expert Systems in Agriculture

Peart (1989) describes numerous potential applications of expert systems in agriculture. Computer scientists and agricultural researchers have developed some successful applications of expert systems to solve problems related to agriculture. Peart (1989) reported that with the implementation of computer-based expert systems, production levels can be increased by making intensive use of available information on all related issues from the growth process of the crop to its marketing. For example, an ES can help in successfully solving insect problems, diseases caused by fungi or nutritional problems. Annual planning of crop rotations, when to rent land, when to buy or sell land, make major machinery purchases can also be done with the help of a computerised based decision support system (Edwards *et al,* 1992). Expert systems can be used as tools for summarizing information and knowledge, selecting among alternatives, exploring and evaluating alternative scenarios, optimizing procedures and system performance, assessing risks, diagnosing problems, identifying specific objects and conditions, such as weeds and diseases, controlling machines and devices, and teaching non-experts the problem solving approaches of experts (Holt, 1989). Extension agents can also use expert systems to update research findings emanating from the research station (Pasqual, 1994).

Morrison *et al*, (1989) designed an ES, PLANTING to systematically develop specifications for soil-engaging components on conservation planters, drill and seeders. It was intended for use by farm advisors when consulting with farmers on adoption of conservation tillage. The designers were of the view that as conservation tillage technologies have become accepted procedures for accomplishing conservation goals and for economical crop production, thus an up-to-date technology transfer techniques should be made available to the advisors and the farmers through the means of an ES. At the time of development of PLANTING in 1986, there were an estimated 44 kinds of planters and 121 kinds of drills and air seeders available in the USA for conservation seeding (No-Till Farmer, 1986a, 1986b). Additionally, many add-on components were also available from several sources.

Considering all of the soil-engaging machine components, they estimated that there may be as many as 864,000 possible combinations of components which could be selected for planting machine (Morrison *et al,* 1986). To find the best combination, they thought, an ES (PLANTING) was needed.

Van Den Ban and Hawkins (1988) quoted the glasshouse horticulture industry where large savings can be made in energy requirements for heating if an experts' advice is implemented. Jorgensen *et al,* (1992) reported extensive use of ES in pig production industry in Denmark. In a country where more than 17 million pigs are slaughtered each year, the National Pig Breeding, Health and Production Committee is responsible for management and co-ordination of breeding work and production, and thus for the development of an ES for pig producers.

No-T**i**ll **E**xpert (**NOTE**) system developed in the current study is likely to be useful for the extension agents in assessing the acceptance or rejection of No-Till under the given conditions.

2.3.1 Advantages of an Expert System

Expert systems which consist of a knowledge-base for evaluating management decisions and to simulate models forecasting the effects of different farm management are updated regularly with new information on the subject. Expert systems help research organisations in recommending the most suitable farming technique. Edwards *et al*, (1992) summarised the advantages of expert systems as follows:

1. They provide consistent recommendations.

2. Rules and information may be checked and edited.

3. Central updating and distribution of computer disks to regional advisors in an efficient way of keeping advisors up to date.

4. All relevant information is contained within a single system, and can be cross-referenced, allowing advisors rapid access.

5. The collection of data into one system allows comparison between management options, and should lead to rigorous, economically sound decisions.

6. Expert systems allow less experienced users to reach a quality of recommendation similar to that of recognised experts, thereby leaving experienced experts time to concentrate on unusual and changing problems.

2.3.2 Expert systems for extension staff

Rogers and Monypenny (1984) identified the use of ES in the agricultural extension activities. They described that by using an ES it will be possible for individual farms to be run through the farm models so that individual producers, with the help of extension officers, can see the implications of their decisions, particularly those with regards to uptake of research findings emanating from the research station. Thus, if the relationship for the rate of technology uptake prove to be reliable, the ES will be helpful to extension officers with regard to the 'packages' which are devised, and the extension methods which are selected for disseminating the new technology (Rogers and Monypenny, 1984).

Edwards and McGregor (1992) reviewed the literature and reported that the number of systems actually being used by extension agents and others providing agricultural advice is difficult to ascertain; it appeared that a high proportion of developed systems occurred within the fields of engineering and financial management (Table 2). However, given effective development, computer-aided information systems are likely to become an important part of agricultural extension. Expert systems allow the combination of the advantages of using mass media technology in order to deal with the requirements of the individual farmer. In another study in the UK, ADAS (1985b) observed that out of 175 farmers from England and Wales, 44 per cent having more than 200 hectares were satisfied with on-farm computer systems. The study concluded that this percentage seemed a fair indication that large farmers tend to be more inclined towards on-farm computer systems.

Table 2 Reported number of expert systems in various agricultural areas (1982-1990)

Subject Area	Developed	Development	Prototype	NA*
Pest Management	4	6	8	32
Resource Management	1	-	-	10
Irrigation & Water	1	1	1	7
Financial Management	2	-	1	3
Farm Management	-	-	-	4
Machinery	6	-	1	16
Crop Production	10	1	6	25
Crop Storage	-	1	-	4
Livestock Production	1	-	3	14
Forestry	-	1	-	7
Horticulture	1	-	1	3
Glasshouse Control	3	-	1	4
Building Design	6	1	1	1
Miscellaneous	3	1	2	9
Total	38	12	25	139

NA* Literature on these expert systems is not available

Sharifi and Keulen (1994) felt that because of the diversity and complexity of the processes involved in agricultural systems (ecological, agronomic, social and economic), comprehensive techniques required considerable amounts of data from various disciplines. Ginzberg *et al,* (1982) and Van Diepen *et al*, (1991) discussed some of the operational and methodological constraints that prevent full integration of existing and collected data into management decisions. They identified following constraints:

- Complexity of the system and decision environment.
- Requirements for high-quality experts.
- Different formats: data are collected by different departments and disciplines using different methods.
- Lack of tools for analysis and integration.
- Lack of consistency between the available data and data required.
- Operational constraints; in an agricultural environment, data collection, manual organisation and processing are inefficient, if not impossible.

The above mentioned constraints constitute severe limitations in the use and integration of farm data into management decisions. The use of computer based expert systems can remove some of these constraints and enhance the quality of planning and management (Sharifi, 1992). It is vital that the amount of information issuing from computer programs for extension workers should be limited to that which is essential for making the particular decision in question. Computer programs should also abide by farmer criteria in relation to both data input and information output (Blokker, 1984). These criteria can be incorporated into the relevant program, and it may be possible for users to select their own individual range of criteria from a wider menu.

2.4 Components of An Expert System

Expert systems have a number of major system components and interface with individuals in various roles. These are illustrated in Figure 1:

According to Merritt (1989) the major components of any ES are:

- Knowledge base - a declarative representation of the expertise, often in **IF-THEN** rules;
- Working storage - the data which is specific to a problem being solved;

- Inference engine - the code at the core of the system which derives recommendations from the knowledge base and problem-specific data in working storage;

- User interface - the code that controls the dialogue between the user and the system (s).

To understand an ES design, it is also necessary to understand the major roles of individuals who interact with the system. These are:

- **Domain expert(s)** - the individual or individuals who are currently experts in solving the problems, the system is intended to solve;

- **Knowledge engineer** - the individual who encodes the expert's knowledge in a declarative form that can be used by the ES;

- **User** - the individual who will be consulting with the system to get advice which would have been provided by the expert(s).

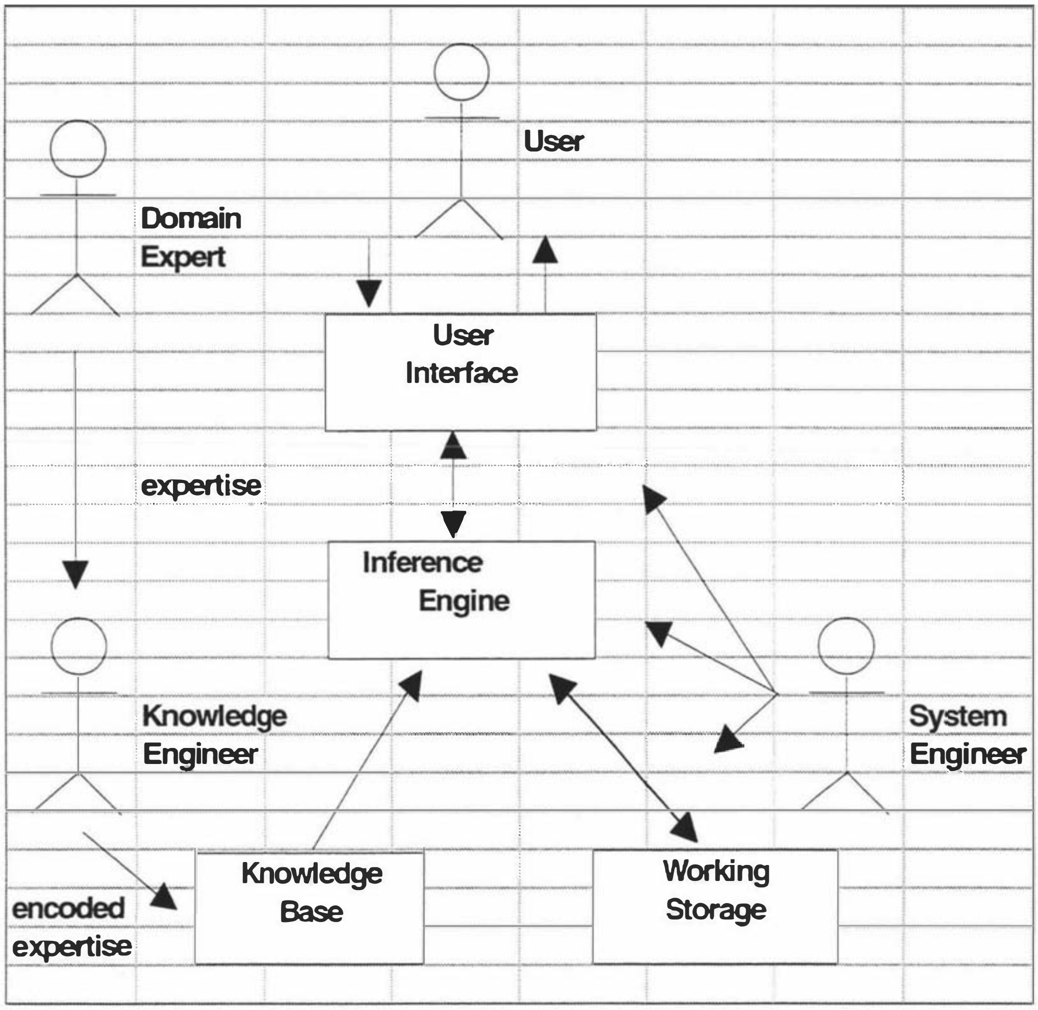

Figure 1 Expert system components and human interfaces
Source: Building Expert Systems in Prolog (Ed) Merritt, D. (1989) pp. 2

There are a number of features which are commonly used in expert systems. Some of these features include:

➢ **Goal driven reasoning or backward chaining** - an inference technique which uses **IF-THEN** rules to repetitively break a goal into smaller sub-goals which are easier to prove. It is an efficient way to solve problems that can be modelled as "structured selection" problems. Thus, the aim of the system is to pick the best choice from many possibilities.

➢ **Coping with uncertainty** - the ability of the system to reason with rules and data which are not precisely known. In some cases the final answer is not known with complete certainty. The ES must therefore be able to deal with uncertainty.

➢ **Data driven reasoning or forward chaining -** an inference technique which uses **IF-THEN** rules to deduce a problem solution from initial data. For many problems it is not possible to enumerate all possible answers before hand and have the system select the correct one. In such cases the inputs vary and can be combined on an almost infinite number of ways, the goal driven approach does not work. For such problems, the data driven approach, or forward chaining is used where the inference process is different from backward chaining. The system keeps track of current state of problem solution and looks for rules which will move that state closer to a final solution.

➢ **Data representation -** The way in which the problem specific data in the system is stored and accessed is of vital importance in an expert system because in all rule based systems, the rules refer to data.

➢ **User interface -** It is the portion of the code which creates 'an easy to use' ES. The acceptability of an ES depends to a great extent on the quality of the user interface. The easiest to implement interfaces communicate with the user through a scrolling dialogue on screen. The user can enter commands, and respond to questions. The system responds to commands, and asks questions during the inferencing process.

➢ **Explanations -** Some expert systems have the ability to explain the reasoning process that it used to reach a particular recommendation. In such cases the system explains which rules were used during the inference process. Thus, it is possible for the system to provide those rules to the user as a means for explaining the results.

Lucas and Gaag (1991) contend that an ES is now rarely written in a high-level programming language. It is frequently constructed in a special, restricted environment, called an ***expert system shell***. The *shell* is a piece of software which contains the user interface, a format for declarative knowledge in the knowledge base, and an inference engine. The knowledge engineer uses the *shell* to build a system for a particular problem domain. Shells are highly specialised and suitable for range of tasks. They are most suitable when the nature of the problem is well understood, and furthermore, the structure of the knowledge being captured is similar to the knowledge representation structures offered by the shell (Uschold *et al,* 1989). The low cost, most popular shells are simple rule-based tools. These shells are usually capable of backward chaining, and commonly utilize certainty factors. More recently, several other tools for building expert systems, like special-purpose programming languages, have also become available, where a separation between knowledge and inference is enforced. These systems are called *expert system builder tools.* More costly rule-based tools provide the additional capabilities of forward chaining and some furnish a means of structuring rules into hierarchically arranged sets with the capacity for multiple instantiation and inheritance (Biondo, 1990). With improved inferencing capabilities of newly available shells, it is now possible that even large expert systems can also be built with almost no knowledge on programming (Payne and McArthur, 1990).

2.5 Expert systems development methodologies

Hayes-Roth *et al,* (1983) outlined the following five stages in development of a knowledge based ES. These are:

1. Identification

2. Conceptualisation

3. Formalization

4. Implementation

5. Testing

The implementation stage involves the development of a prototype system, and in the next stage evaluation of the prototype system is done.

Harmon and King (1985) outlined six phases in the development of an ES. These are:

1. Selection of an appropriate problem

2. Development of a prototype system

3. Development of a complete expert system

4. Evaluation of the system

5. Integration of the system

6. Maintenance of the system

2.5.1 Construction of an expert system

A wide variety of expert systems meeting basic functional properties of ability to process non-numeric information, and the ability to communicate with the user at the user's level, have been constructed. Most of these are the *rule-based* expert systems. Engel *et al*, (1989) have also described that the most popular representation structure used in expert systems are rules. According to them the performance of an ES can be improved by supplying various sorts of knowledge in the system. This type of knowledge comes in form of rules.

Although many other paradigms are available for building expert systems, rules have maintained their prominent position because of many users' desire to avoid programming. These rules are usually English-like sentences and Jackson (1986) called them as 'condition-action rules'.

2.5.1.1 What are rules?

Rules represent conditional knowledge that is quite similar to the way humans express it. Gonzalez and Dankel (1993) described rules as an important knowledge representation paradigm. The knowledge base that contains information specific to the problem at hand is expressed in the form of rules which usually are in a form of:

if *condition* **then** *action*

where *condition* and *action* are simple conjunctive expressions.

Their principal use is in the encoding of empirical associations between patterns of data presented to the system and actions that the system should perform as a consequence (Jackson, 1986). Therefore the rules are expressions which describe that if the antecedents (*condition*) are true, then the consequents (*action*) are also true. Cleal and Heaton (1988) identified four types of rules:

2.5.1.2 Identification rules

- *Identification rules* - which classify objects by their properties. For example;

`If X has a moustache then X is male'

2.5.1.3 Causal rules

- *Causal rules* - which link cause and effect. For example;

  `If it rains then the grass will grow'

2.5.1.4 World fact rules

- *World fact rules* - which are based on general knowledge of the world. For example;

  `Spark plugs are a likely cause of problems in petrol engines'

2.5.1.5 Domain fact rules

- *Domain fact rules* - which are statements of definitions which are true within the domain under consideration. For example;

  `If the data arrived with the wrong check digits, then it must have been corrupted somewhere along the communications link'

2.6 Task of the inference engine

The knowledge base may contain hundreds of such rules and the task of the inference engine is to piece together logical chains of reasoning based on these rules to verify a conclusion. The inference engine uses these rules and the available facts to assert additional facts into the knowledge base. When a new fact is placed in the knowledge base, and the inference engine "sees" the new fact, it must check whether that fact matches any antecedent of rules in the knowledge base. This process, which is known as **matching**, is one of the most important components of every inference engine. To match a fact, the pattern of the rule clause must match a pattern in the knowledge base. Once the inference engine has matched a rule's antecedents, it **fires** the rule by asserting the rule's consequent into the knowledge base. For example, if some animal identification rules are being constructed, we can reach towards a conclusion with the following pair of rules:

Rule 1	**If** an animal flies
	Then it is a bird
Rule 2	**If** an animal is a bird and lives by the water
	Then it is a duck

With above set of rules it can be verified that an animal that flies and lives by water is a duck.

Consider some canning line application problems for which an ES has to be built. The first task in this case should be to build a simple knowledge base representing the linkages between abnormal sensor readings and potential machine failures. To do this combination the following has to be used:

- facts about the canning plant
- facts representing advice for the operator
- rules representing the relationships between those

Rules and facts are the basic building blocks of a knowledge base. Facts may be thought of as assertions that certain things are true and stated in English. Some facts for the canning plant might include:

The oil pump is running hot.
The oiler needs to be shut down immediately.
The nozzle on washer (2) is clogged.

Rules logically connect these related facts in English sentences as under:

IF the oil pump is running hot, **THEN** the oil pump needs maintenance.

If there were multiple pumps, we could write a separate rule for each pump:

IF the washer pump is running hot, **THEN** the washer pump needs maintenance.

IF the paint pump is running hot, **THEN** the paint pump needs maintenance.

However, if there were a large number of pumps, such approach becomes tedious. In such cases a single rule (**IF** any pump is running hot, **THEN** that pump needs maintenance) by using **variables** will be presented as under:

IF pump X is running hot, **THEN** pump X needs maintenance

The translation of an English sentence (based on example mentioned above) into a rule can be described as under:

English sentence	If the oil pump is running hot, it needs maintenance immediately.
Rule in the knowledge base	**IF** the oil pump is running hot **THEN** the oil pump needs maintenance immediately
What the rule means to the inference engine	if the statement that "oil pump is running hot" is found in the knowledge base, assert "the oil pump needs maintenance immediately" as a new fact.

The way of overcoming some of the problems of large knowledge bases is to partition the system into smaller subsystems and this approach has produced the **`blackboard'** systems technique (Nii and Aiello, 1988). In such architectures the rule base is divided into different knowledge sources, each of which encapsulates those pieces of knowledge that are relevant to a particular part of large problem the system is trying to solve. Knowledge sources can look at the blackboard to find information that might be relevant to them and when they derive new conclusions these in turn are placed on the blackboard for the use of other knowledge sources. In the above mentioned pump example, it may be observed that while writing rules, the first action was to break down the logic being represented into a series of discrete steps, and each step corresponded to a different stage of the decision-making process. However, the difficulty of constructing such a breakdown depends on the degree to which the logic has been documented beforehand. In many cases the knowledge engineer must reconstruct the decision-making process through direct observation and gathering whatever written documentation is viable (Payne and McArthur, 1990).

Due to a large number of variables in NOTE, the blackboard technique is used for its construction as well as for the validation process of NOTE.
Rule-based systems are classified into two categories (Buchanan and Wilkins, 1993):

- Pattern matching
- Parameter driven

Each category has specific knowledge representation and associated deductive mechanisms. Correspondingly, each approach is suited to a different class of problems having different needs.

The pattern matching system has three elements: *facts, rules* and a *reasoning strategy.* Knowledge about the states or value of objects that describe the problem is contained in *rules.* The *reasoning strategy* mechanism that uses the rules to reason about the problem is contained in a group of functions collectively referred to as the *inference engine.*

Rules also describe static relationships between facts. In a pattern matching system, the premise or **IF** portion of an **IF-THEN** rule is made of clauses that must evaluate to either **TRUE** or **FALSE**. These are called *predicate* clauses. *Predicate* clauses may contain constants, variables, or both.

2.6.1. Forward chaining process

A forward-chaining pattern matching system starts with a pre-defined set of facts. All rules whose **IF** or premise portion can be made **TRUE** by substituting those facts or premise variables are fired. In other words, if the **THEN** or *consequent* portion is to be evaluated then any new facts inferred will have to be added to the facts list. These new facts may cause the premise clauses in other rules to become **TRUE** causing them to fire and to add yet more facts to the list. This process continues until either the goal fact has been determined, or until there are no more rules that may be applied. Forward chaining is used when the cost or inconvenience of gathering data is low and there are relatively few hypotheses to explore.

NOTE has two sets of rules. The forward chaining process links some of these rules as described under:

1. **IF**

   the straw residue from the previous crop was removed

   THEN

   No-Till/Conventional Tillage both are fine

2. **IF**

   farmer has an access to a No-Till drill

   THEN

   No-Till is recommended

3. **IF**

   farmer does not have access to a No-Till drill

   THEN

   farmer should continue with the conventional tillage practices

In the forward chaining process, if the statements at No. 1 and No. 2 match, NOTE recommends No-Till, otherwise a recommendation for continuing with conventional tillage appears on computer screen.

2.6.2 Backward chaining process

Conversely, the backward-chaining pattern matching system is appropriate when a user supplies much of the data, and when the user cares about the order in which data are requested. Because of available alternative solutions, this type of reasoning is goal directed and does not require all relevant data to be available at the time inferences are begun (Biondo, 1990).

Parameter driven systems are similar to pattern matching systems in having *facts, rules* and a *deductive mechanism*, but differ in the inferencing scheme and the knowledge representation used for support. Facts in a parameter driven system are represented by parameters. Parameters may take on various attributes called *properties*, as well as *values*. Properties are used to improve efficiency; for example, to restrict the range of possible values and to tell the inference engine where to find rules that pertain to each parameter. For example, assuming the goal of determining an adjustment to make onto a pasta dryer, Figure 2 shows a simplified knowledge base for the dryer control problem. Plant and Stone (1991) named this section of the knowledge base as "antecedent - consequent rules".

Rule 1. IF time = 30-60 minutes, and
product moisture = too wet, and
product checking = none,
THEN adjustment = decrease humidity

Rule 2. IF time = 30-60 minutes, and
product moisture = severe,
THEN adjustment = increase humidity and decrease belt speed

Rule 3. IF time >= 60 minutes, and
product moisture = too dry, and
product checking = none,
THEN adjustment = increase belt speed

Rule 4. IF time >= 60 minutes, and
product moisture = satisfactory, and
product checking = slight,
THEN adjustment = increase temperature

Rule 5. IF wet basis moisture content >= 15%,
THEN product moisture = too wet

Figure 2 Pasta dryer control rules

NOTE uses the backward chaining process when the farmer selects either No-Till or Conventional Tillage, and asks to know what are the most suitable conditions under which these practices can be adopted. The following example elaborates the use of the backward chaining process in NOTE:

1. **IF**

   the farmer wishes to adopt No-Till

   THEN

   farmer should ensure that:

(a) The soil type is either sandy, sandy loam, or any well drained soil.

(b) Farmer has access to a No-Till drill.

(c) Herbicides chemicals are available.

(d) The farm is out of Rice Stem Borer (RSB) affected area.

Therefore, in the backward chaining process, first a goal is set (selection of a tillage technique, in case of NOTE) and then the ES elaborates as to how that goal can be achieved.

2.6.3 Ranking of rules

The rules are required to priortize in order to indicate the likelihood of more than one solution in the cases where more than one line of reasoning has survived to reach a final conclusion. In such cases, one advantage of numerical degrees of belief is that the best alternative can be chosen by a simple arithmetic comparison. However, when justifications are represented qualitatively by endorsements, rules must be supplied that will indicate when one rule has a better justification than the other. In appearance, ranking rules are very similar to ordinary antecedent-consequent rules. The difference is that ranking rules do not attempt to add or remove conclusions. They merely annotate existing ones after the belief revision process has been completed (Clark, 1990). In NOTE, rules are divided in smaller sub-rules and these are triggered in order of their importance, thus the need of numerical or arithmetic ranking did not arise.

2.7 Methods of knowledge acquisition

Knowledge may be elicited directly from the expert, through simple questioning or it may be indirectly elicited through observation and through other sources of expertise e.g. training manuals. Cleal and Heaton (1988) identified following four broad-classes of knowledge acquisition:

- **Interview Analysis**. This involves the knowledge engineer in studying verbal protocols, questionnaire responses etc. This provides information directly from the expert. Provided that the questionnaire has been well designed, it is easy to analyze and to translate the information into terms which the system designer can use. However, there are several problems associated with interview analysis. First, the knowledge engineer has to know what questions to ask. This can be especially hard if the knowledge engineer has little knowledge about the area of expertise. Secondly, if the questionnaire is too restrictive, the knowledge engineer may often miss information which are crucial.

Cleal and Heaton (1988) outlined three other techniques for interview analysis as under:

- Problem Discussion: explore the kind of data, knowledge, and procedures needed to solve specific problem.

- Problem Description: have the expert describe a typical problem for each category of answer in the domain.

- Problem Analysis: present the expert with a series of realistic problems to solve aloud, probing the rationale behind the reasoning steps.

Once the expert has provided the basic information and rules the knowledge engineer then should aim at improving the knowledge. This is a three stage process:

- System Refinement: have the expert give a series of problems to solve using the rules acquired from the interviews.

- System Examination: have the expert examine and critique the prototype system's rules and control structure.

- System validation: present the cases solved by the expert and prototype system to other outside experts.

This provides the knowledge engineer with the necessary feedback to assess whether the expert system is meeting the expert's requirement and representing their expertise.

- **Behaviour Analysis**. This requires the knowledge engineer to make observational studies such as making films of the expert. The expert is generally required to verbalise reasons and provide explanations for decisions either during the task, or when reviewing it later. The advantage of such technique is that it does not miss anything. It captures the expert performing the task and may be reviewed, in part, in slow motion or in other ways at the interviewer's leisure.

- **Machine Induction**. Theoretically, this removes the bottleneck, by replacing knowledge acquisition with the much less arduous task of collecting case histories. There are a few limits to the power of this technique, and the obvious one is that it allows only the development of classification rules. This technique also requires a relevant and complete set of criteria to coincidentally generate a rule. The unique advantage of machine induction is that it does offer the possibility of deducing new knowledge. It may be possible to list all the factors which influence a decision, without understanding their impacts, and to induce a rule which works successfully. The technique should certainly be considered where there are plentiful data and a well-defined classification problem to solve.

- **Text Analysis**. This is knowledge acquisition without recourse to an expert but through the use of textbooks and user manuals. Because of the nature of this study, the NOTE is designed by this method. The main advantage in using the text analysis method is that it does not require the knowledge engineer to have a direct and continuous access to the expert(s). While designing the NOTE, it was imminent that due to many other things in the expert's agenda, they will not be available at times to certify each and every statement (rules in case of NOTE). Thus, the textbooks, user manuals, and the literature on the No-Till was used to formulate the rules before incorporating them in the expert system.

2.8 Advantages of rule-based systems

There are three significant advantages of rule-based systems (Gonzalez and Dankel, 1993):

1. **Modularity**: Rule-based knowledge is highly modular as each rule is a distinct unit of knowledge that can be added, modified, or removed independently of the other rules. This gives the knowledge engineer flexibility in developing a knowledge base since it can be developed in portions, tested, and then added to the existing knowledge base. Therefore, the knowledge base can be expanded slowly into its final form.

2. **Uniformity:** Since all knowledge in the system is expressed in exactly the same format, it simplifies the development of the knowledge base (a uniform representation also requires less shifting of thought also).

3. **Naturalness:** Rules are a natural format for expressing knowledge within some domain. Experts logically think about problems and their solutions using the existing situations to point to the desired conclusions.

2.9 Disadvantages of rule-based systems

Disadvantages include (Gonzalez and Dankel, 1993):

1. **Infinite chaining:** Because of the possibility of the same situation occurring through several rules infinite looping (in forward or backward chaining) problem can occur in rule-based knowledge.

2. **Addition of new, contradictory knowledge:** Because of the possibility of introducing new knowledge to solve some problems in the rule-based knowledge, contradicting statements are sometimes introduced, which sometimes, become difficult to locate and correct.

3. **Modification to existing rules:** Another difficulty with rule-based systems occurs when modifications in the existing knowledge are made. One modification sometimes, leads to the need to change, or add, rules.

2.10 Summary

The importance of computer programs in any successful farm use cannot be overemphasized. Phenomenal advances in computer technology have occurred in the last few decades. The room-sized computers of 20 years ago have been replaced by desk-top units that, besides being less expensive, often can do more than their giant ancestor. In the 1970's, expert systems emerged as a new practical approach for applying computers and information to the decision problems faced by management. Since then, computer programs have become valuable tools in agricultural management too. To remain in business, today's agricultural producer must have the best possible information on growing crops, controlling disease, and applying fertilizer, pesticides, and herbicides. Knowledge-based systems offer an alternative way to represent an expert's knowledge about cropping systems and to apply that knowledge to solve problems. Modern information technology can give the farmer rapid access to a large amount of information, helps in selecting the exact information needed for decision-making, and with the assistance of `user-friendly' computer based decision models, reach a best possible decision under the circumstances.

An ES requires a lot of knowledge before it reaches an expert's level of performance. Therefore, the question of how the knowledge is represented is critical in the design of a system. The most common schemes used to represent knowledge are rules. Rules allow us to represent relationships in `**IF** *antecedent* **THEN** *consequent*' to express that the consequent is true if the antecedent is true. Rules are commonly more declarative than the use of conventional languages. One of the key benefits of rule based systems is that the user is not obliged to explicitly specify, or even consider, the flow of control as a rule based program is executed. The rules can be steered either through forward chaining, or through backward chaining to reach to a conclusion. Forward chaining works from known facts towards desired goals, while the backward chaining works from goals to subgoals, and then eventually to known facts.

Chapter-3 Principles of Crop Establishment

3.0 Introduction

In general, the principal factors influencing crop establishment include: seed-bed, seed, and weather (Choudhary, 1990; Wild, 1988; Baker, 1985; and Choudhary, 1984). Gego (1986) estimated potential yield increases due to various agricultural measures and has reported that sowing technology alone (which included seedbed preparation and sowing techniques) contributed to an increase of 15-35%. By tradition, the seedbed had always been the end product of a prolonged sequence of time consuming and energy-intensive cultivation. Often, this carefully prepared tilth served two purposes: it allowed the seed to be placed in the soil at a suitable depth, and it provided appropriate conditions for germination of the seed and early growth of the seedling. While it may be self-evident why good seed is essential for a good crop, factors such as, seed application rate, seed placement depth, the soil type, and ensuring a favourable micro-environment conditions make the process of plant establishment quite complex. This chapter explains the complexity of crop establishment and the need for a computer based expert system in helping and guiding farmers and extension agents in choosing appropriate tillage techniques.

3.1 Seedbed Preparation and crop establishment

Seed needs a warm, moist, well-aerated seedbed, which should be fine enough to give a firm contact between the seed and the soil (Choudhary, 1990). To achieve this, farmers have progressed from little or no tillage through the use of sharpened sticks and wooden tillage tools, to the plough and later to excessive tillage with variety of steel implements, to minimum tillage techniques, and now to No-Till (Wild, 1988).

Originally, the purpose of tillage (McLaren and Cameron, 1996) was to prepare a seed bed in which desirable plants of economic value could germinate and grow. However, there are also other reasons for tillage practices, which include: incorporation of crop residues and fertilisers; the management of surface trash; the control of weeds; the improvement of soil physical conditions, including moisture, aeration and temperature; the control of insects and disease problems; the control of wind and water erosion; the provision of drainage; (Phillips and Phillips, 1984; Cambardella and Elliott, 1992; Angers *et al,* 1993).

Typically, tillage systems were very intensive in nature carrying-out complete inversion of plant residue and pulverisation of the surface to prepare a seedbed. Conventional tillage referred to the methods of seedbed preparation that involved physical soil manipulation by equipment such as a mouldboard plough, disk plough, rotavator, or harrow (Lal, 1979). These tillage practices may differ considerably from area to area and from year to year, depending on specific circumstances. Cutting and loosening of soil to a depth of 15 to 90 cm is considered as a primary tillage operation that is normally done with mouldboard plough, disk plough or chisel plough (loc. cit.). Secondary tillage operations were usually performed after primary tillage operation(s) to improve seedbed level, increase pulverisation, destroy weeds, and chop crop residue (McKyes, 1985).

The use of excessive tillage not only increased soil erosion, but also increased moisture loss (Mannering and Fenster, 1983; Lal *et al,* 1994; and Vyn *et al*, 1994). Coarse textured soils such as sands and sandy loams have a high capacity for water penetration (Kooistra and Noordwijk, 1996). In medium and fine textured soils, such as clay and clay loam, the maintenance of fair sized aggregates is essential for water penetration. Therefore, it is very important to avoid overworking these soils during seedbed preparation. If the soil aggregates are reduced to a fine dust through overworking, the tiny particles will run together during rainfall and seal the soil surface. This seal reduces the rate of water infiltration and can result in severe erosion. The seal or crust also interferes with seedling emergence and consequently affects the crop yields (Hamblin, 1985). The simplest solution is to reduce tillage.

3.2 Alternatives to Conventional Tillage Systems

Various alternatives to conventional tillage have been proposed. Mulch tillage was considered as another way of preparation of soil that ensured maximum retention of crop residue on the soil surface (Ehlers and Claupein, 1994). It is defined as preparation of the soil in such a way that plant residue or other mulching materials are specifically left on or near the surface. This prevents soil erosion and conserves soil moisture due to the mulch left on the soil surface (Lal, 1995). However, heavy residue could also pose a problem for the implements used during seedbed preparation, and seeding can become difficult due to the straw residue (Unger, 1994).

A mulch tillage system does not usually imply the use of chemicals (herbicides) as substitutes for tillage. Mulch tillage practices include a sequence of operations such as cultivation, harrowing, herbicide incorporation and fertilisation followed by spring cultivating, harrowing and packing before seeding. Success for mulch tillage requires proper straw, weeding and disease control (Ehlers and Claupein, 1994).

In the USA, the chemical summerfallow is another system in which vegetative growth during the fall or summer months is controlled with one or more applications of suitable herbicides (Allmaras *et al,* 1994). If properly managed, it may eliminate three to four tillage operations and reduce the risk of soil erosion. However, the control of weeds during the summer fallow season with chemicals require better management knowledge of herbicides, and it may only be suited to certain soil conditions (Allmaras *et al*, 1991).

The belief that no practical substitute for tillage exists faded away when experiments showed that much of the tillage can be replaced with timely herbicide applications without reducing the effect of summerfallow (Unger and Skidmore, 1994). Then, with the increasing cost of fuel, concern over erosion and the issues of maintaining good soil structure the concept of 'minimum tillage' was introduced. Minimum tillage does not define a system of tillage, but generally refers to a system with fewer tillage operations than are common with conventional tillage systems. Research at Melfort, Saskatchewan, Canada, has indicated that for general broad-leaf weed control, herbicides may be substituted for a portion of the tillage during the season, thus reducing the total amount of tillage required (Larney *et al,* 1994). Combination treatments were sometimes used depending on weather conditions and weed problems, and were more economical than either tillage or chemicals alone (loc. cit.). Treatments where chemicals were used, were as effective as tillage for increasing the N and P content of the soil (Nyborg and Mahli, 1989). Increasing interest in reducing the number of tillage operations required for seedbed preparation finally led farmers to No-Till. No-Till farming is an economically viable, erosion proof crop production system in which the crop is planted directly into the previous crop's stubble with minimum soil disturbance (Stonehouse, 1997, Stonehouse, 1995, Lal, 1979). Generally pre or post-harvest treatment of all No-Till fields is recommended for control of weeds (Papendick and McCool, 1994). Unger and Skidmore (1994) reported that annual weeds are reduced when No-Till is practised for a number of years. The reason appeared to be that, weed seeds that remained on the soil surface did not germinate readily (Unger and Skidmore, 1994; Reeves, 1994). Good crop establishment can also be achieved under No-Till if the task of controlling weeds, disease, managing trash, improving soil fertility and placing seed at a shallow depth into moist soil operations were performed in a timely manner (Radford, 1986; Rainbow *et al,* 1992). However, on clay soils, decrease in crop yields under No-Till have been reported, and this has been attributed to lack of aeration in such soils (Lal *et al,* 1994). The trash on the No-Till seedbed also imposed a problem at the time of direct-drilling (Christian and Ball, 1994). Therefore, burning of residue prior to seeding had been attempted in order to obtain effective seeding in the UK (loc. cit.). In the USA, removing straw by burning generally resulted in higher spring wheat emergence, dry matter production, tillering and yield (Lal *et al,* 1994). The reasons for better crop development on No-Till plots when straw was removed by burning were attributed to more effective seeding in the absence of trash, warmer soil temperature, and higher nitrogen availability as compared to No-Till plots with straw spread (loc. cit.). However, since the early 1980s, new regulations restricting farmers' option to burn straw have been gradually introduced in various parts of Europe, and since 1992, the burning of straw and stubble has been banned in England and Wales (Christian and Ball, 1994). This has resulted in many farmers, who had opted for reduced tillage or direct drilling, returning to conventional tillage systems (Cussans *et al,* 1990). Though, availability of No-Till drills that are capable of operating in trashy conditions would probably again encourage them to adopt reduced tillage methods.

The limitations, and advantages of reduced tillage techniques are discussed below.

3.2.1 Limitations

- Although seeding equipment is improving, it is not totally successful under all conditions with respect to seed and fertiliser placement as well as penetration into a hard, trashy surface.

- Herbicides are expensive and must be used for vegetation removal prior to crop emergence.

- More managerial attention is required. For example, correct timings of herbicide application at recommended rates are prerequisite to getting an efficient weed control.

- No-Till may not succeed on fine textured, poorly drained soils that are easily compacted.

- Perennial weed control becomes increasingly important and expensive.

- Trash management may be difficult in certain years.

- Potential exists for insect and disease problems, especially when the organisms overwinter on previous crop residues.
- Soil amendments are not incorporated into the soil except by banding near the seed.

3.2.2 Advantages

- Fuel and time are saved since fewer field operations are required.

- Plant residues, which remain on the surface, protect the soil against water and wind erosion.

- More area can be planted per unit of time.

- Soil dries less than with conventional tillage, therefore moisture is conserved in the root zone.

- Populations of some weed species may decline since weed seeds are not incorporated into the soil and stimulated to germinate by aeration and tillage.

- Reduced capital investment in tillage equipment.

- Retention of soil organic matter levels.

3.3 Factors affecting the choice of a tillage system

Tillage is a labour-intensive activity in low-resource agriculture practised by small land-holders, and a capital and energy-intensive activity in large-scale mechanized farming (Lockeretz, 1983; Lal, 1991). For any given location, the choice of a tillage practice will depend on crop, soil, climatic, and socio-economic factors (Lal, 1980; Ervin and Ervin, 1982; Napier *et al,* 1984; Lal, 1991; Napier *et al,* 1991, Stonehouse, 1997; Stonehouse, 1995). The most common tillage practices and their achievable tilth depths are given in Table 3 (Triplett and Sprague, 1986). Though not mentioned in the table, Triplett and Sprague (1986) also reported change in soil moisture contents, density, and temperature due to the variability in tilth depths under various tillage practices. The amount and distribution of soil organic matter resulting from decaying of crops residue also alters with a change in tillage technique (Cruz, 1982; Fernandez, 1976). International Institute of Tropical Agriculture, Ibadan, Nigeria, (Phillips, 1984), reported manpower requirements for No-Till and conventional-tillage methods (Table 4). More work on evaluation of various tillage techniques in comparison to reduced tillage techniques has been reported by Frye (1984); Collins *et al*, (1980); Griffith and Parsons (1980); Parson (1980); Phillips and Phillips (1984); Triplett and Sprague (1986); Lal *et al*, (1994); Carter (1994); and Uri, (1996). Therefore, a reasonable knowledge of such studies could help in identifying the factors affecting the choice of a tillage system.

The adoption of new tillage techniques has been slow and this was attributed partly to a natural reluctance to change from any proven tillage practice (Riley *et al*, 1994). For example, in Sweden, the possibility of No-Till emerged in the early 1970s (Riley *et al*, 1994), and the data collected by Lessiter (1984) indicated that only 4% of all crop land was treated with No-Till in 1983. Similarly, in the UK, only about 8-10% of winter cereals were believed to be under No-Till at the end of the 1970s (Christian and Ball, 1994). In Western Australia, where Australia's No-Till was pioneered, this proportion was higher as in 1984, about 30% of cereals (two million ha) were grown under No-Till. All over Australia, about 3 million ha of crops (less than 20% of all crops), was grown under No-Till, some of this without herbicide (Amor *et al,* 1984; Conacher and Jeanette, 1986). In 1991, No-Till was utilized on only 4% of the field crop area while 65% of the cropping area in southern Ontario, Canada was mouldboard ploughed (Vyn *et al*, 1994). In spite of these reports, Triplett and Sprague (1986) commented that reduced tillage techniques were becoming common practice in many parts of the USA, and they anticipated that nearly 45% (62 million ha) will be under No-Till in the USA by the year 2000. Lately, Olofsson, (1993) also reported an increase in area under No-Till in Sweden, where 25% of the winter rapeseed area was under No-Till in 1987 (Olofsson, 1993). Lessiter, (1997) reported that "No-Till made up 42% of all conservation tillage acres and 15.1% of all acres farmed in 1996."

Table 3 Tillage Systems and their achievable tilth depths

S Y S T E M	Typical Depth of tillage (cm)
Primary full width tillage (15-cm depth or more)	
Mouldboard Plough, disk and/or field-cultivate twice	15-25
Chisel Plough (10-cm twisted points), disk twice	20-25
Chisel Plough (5-cm straight points), disk twice	20-25
Primary tillage disk, shallow disk twice	15-20
Shallow full width tillage (< 15-cm depth)	
Disk and/or field cultivate twice	10-15
Rotary tillage once or twice	5-10
Stubble-mulch for wheat (wide V-sweep plus rod weeder)	5-10
Wide strip tillage (10-38 cm)	
Till-plant in ridge	2-8
Strip rotary tillage	5-10
Narrow strip tillage (< 10 cm)	
Subsoil, plant	30-35
No-Till, plant	5-10

Source: Triplett and Sprague (1986) In: No-Tillage and Surface-Tillage Agriculture. The Tillage Revolution. p. 21

From above the discussion, it is obvious that many factors enter into the selection of the appropriate tillage system. The criteria for selection differs among regions, climates and economies (Napier *et al*, 1991, Stonehouse, 1997; Stonehouse, 1995). Lal (1991) added factors like available farm power, soil characteristics, landscape, the nature of the crop to be grown, and the social status of the farming community.

These factors are discussed in Chapter-5.

Table 4 Manpower requirements for No-Till and conventional establishment systems

	OPERATION	NO-TILLAGE (man-hr/ha)	CONVENTIONAL (man-hr/ha)
Field Preparation			
a.	Slash, burn and till manually		180
b.	Controlled droplet applicator (CDA) spraying with systemic herbicide	5	
Seeding			
a.	Manual planting into tilled soil with machete (low plant population)		20
b.	Auto-feed "punch" planting (maize-cow pea 75 x 25)	30	
Weed Control			
a.	Manual weeding twice		280
b.	CDA spraying with pre-emergent herbicide	5	
Fertiliser Application			
a.	Banding by hand along rows		25
b.	Using a hand propelled band applicator	6	
Plant Protection			
a.	Knapsack spraying of insecticide		10
b.	CDA spraying of insecticide	2	
Total man-hours spent to establish crop on one hectare of land (not including harvesting)		48	515

Source: Phillips (1984) In: No-Tillage Agriculture, Principles and Practices. p. 267.

3.3.1 Farm energy budgets and manpower requirements

Energy used for tillage accounts for approximately 11% of total direct farm energy use, while fertilizer application accounts 0.7%, and pesticide application accounts for 0.8% (Anon., 1987). Thus, a reduction in farm energy use due to the reduction or elimination of tillage would be expected to be substantially in excess of the increase in energy use for fertilizer and pesticide applications (loc. cit.). Earlier, Wood (1981) had estimated that fuel and electricity together accounts for between one third and two third of farm energy budgets. Since tractors operations were responsible for as much as 70% of fuel consumption, there were direct advantages in reducing fuel use. The reduction in fuel consumption could be achieved through careful selection of the machinery, its maintenance, working speed, and operating on appropriate soil types and depths (Taylor, 1977; Wingate-Hill and Marston, 1980; Anon., 1981). The data in Table 5 illustrate some of the differences in fuel consumption, total energy and labour used under different tillage systems. Table 5 shows that savings of 20 litres/ha or more of fuel, and halving of both time taken and costs to establish a crop, were common when comparing No-Till with conventional tillage. Vaughan *et al*, (1977) also analysed energy inputs for corn and soybean crops in the USA and showed that fuel, and usage of machinery could be halved by converting from conventional to No-Till. Thus, knowledge of the farm energy budget becomes an important factor in making a choice among various tillage systems.

3.3.2 Managerial expertise

Success of any tillage technique is also dependent on the managerial expertise of the farmer (Thomas *et al*, 1984). The management problems vary between regions, and also between and within individual farms, as well as from season to season (Unger and Skidmore, 1994). For example, there are a variety of tractors, agricultural implements and chemicals to choose from. A poorly timed decision on what herbicide to use, and when to apply it, may depress yield to an extent that the cost of using a herbicide may not be justified (Unger and

Skidmore, 1994) or poor timing of chemical use may mean that satisfactory weed control is not obtained. Herbicide effectiveness can also be reduced by a range of other factors such as climate, soil type, weed tolerance, crop residues, or presence of pests and diseases associated with reduced tillage techniques.

Table 5 Energy, cost and time factors in minimum and conventional cultivation

Green, Hartley and West (1977)	**Energy** (GJ/ha)	**Fuel** (l/ha)
- Plough/cultivate	2.26	67.4
- Direct-drill	1.02	18.5
Poole (1979b)		
- Conventional (Plough, cultivate, scarify)	2.630	71.0
- Minimum tillage (Spray, seed combine)	0.370	5.2
Lindwall (1979)		
- Conventional	9.00	
- No-till	6.94	
Ellington and Reeves (1978)		
		Cost to sow crops ($/ha)
- Conventional	2.898	20.50
- Direct-drill	0.378	10.62
Vaughan *et al*, (1977)		
	Labour used Hours/acre	**Fuel (l/ha)**
- Conventional	2.24	71.25
- No-till	0.97	27.75
Crosson (1981)		
	Estimated total per ha cost ($)	
	Conventional tillage	**Conservation tillage**
- Cotton	279	264
- Corn	165	154
- Sorghum	114	101
- Wheat	79	68
- Soybeans	105	95

Source: Herbicide in Agriculture: Minimum Tillage, Science and Society (Eds.) Conacher and Jeanette (1986). pp. 69.

Quoting an example from the USA, Unger and van Doren (1982) reported that whereas at the turn of the century it took a farmer 150 minutes to produce 25 kg of corn, by the mid 1950s this had halved, and now it requires a mere three minutes. Similarly, in Australia, the time taken to plough and seed a crop under No-Till has been reduced by about two and a half times, from 210 hours per 400 ha, to 82 hours (W.A. Dept. Agric./Kondinin Districts, 1981). In the USA during the 1960s and 70s, the amount of hoe labour required in some cotton areas was reduced from 48 man hours per acre (120/ha), to 13 man hours per acre (33/ha) through herbicide use. The cost of labour decreased from as much as $500/ha, to as little as $40/ha where herbicides were used in combination with cultivation (Unger and van Doren, 1982). In addition, under reduced tillage techniques the use of wider machines, reduction in the number of seedbed preparation operations, and reduced wear and tear, contributed towards cost savings. The benefits of these savings were further enhanced by the ability to sow additional crop in few cases (Blaine *et al*, 1988; Gill and Daberkow, 1991). Conacher and Jeanette (1986) quoted Elias (1969) reporting that such savings have not been confined to developed countries. For example, herbicide use in Sri Lanka, Malaysia and Japan almost halved working time (hours/ha) in rice fields and enabled land preparation and planting operations to be reduced to 5-6 days from 2-6 weeks and permitted multiple cropping. Thus, by adopting correct management techniques, reduction in the time involved in sowing and in harvesting can be achieved (Unger and van Doren, 1982). Therefore, the managerial skills of farmers should not be ignored in selection of any particular tillage method.

3.3.3 Crop yields

The crop yields under various tillage systems vary with soil type, climates, seasonal condition, and type of management (Conacher and Jeanette, 1986). Nevertheless, given adequate soil water, favourable precipitation, good drainage, reasonable soil fertility and good weed control, crop yields under minimum tillage can be equal to or higher than under conventional systems (Unger and McCalla, 1980; Djurhuss, 1985). Lindwall *et al*, (1979) reported that if all factors were equal, the moisture conserved alone would enable shallow seed placement, good crop establishment and higher grain yields. For example, maize under minimum tillage yielded 15% more than the conventionally tilled crop. In Australia too, minimum tillage practices out-yielded conventional practices over an eight year period of wheat cultivation (loc. cit.). Table 6 shows the tillage effects on crop yields for different

Table 6 Tillage effects on Crop Yields for different Soils of the Semi-arid Regions of West Africa

	Ploughing	Minimum Tillage
	(kg/ha)	
Senegal		
Groundnuts	2,029	1,536
Millet	1,635	1,546
Maize	3,014	1,515
Rice (Rainfed)	3,417	1,765
Togo		
Groundnuts	1,111	666
Maize	1,991	608
Sorghum	3,392	1,259
Ivory Coast		
Maize		
Class 1 soils[1]		
Class IRAT 81	4,355	4,510
CJB	3,125	2,920
Class 2/3 soils[2]		
IRAT 81	3,340	2,740
CJB	2,180	1,800
Rainfed rice		
Class 1 soils		
Variety IRAT 13	3,240	3,340
Moroberekan	1,700	1,850
Class 2/3 soils		
Variety IRAT 13	2,200	1,900
Moroberekan	1,240	1,560

1 = Class 1 soils: soils with good water retention properties.
2 = Class 2/3 soils with gravel content, poor water retention properties.

Source: Triplett and Sprague (1986) In: No-Tillage and Surface-Tillage Agriculture. The Tillage Revolution. pp. 280

soils of the semi-arid regions of West Africa. The table shows that No-Till may not be feasible for all soils conditions or climates, but it seemed to have been feasible in the sub-humid regions of Ivory Coast. Thus, comparison of crop yields under various tillage methods is another important factor which must be considered before choosing any tillage technique.

3.3.4 Other considerations

Availability of suitable tillage machinery is another important factor when making a choice of a suitable tillage technique (Thomas *et al*, 1984). Some of the common problems related to tillage machinery that has reduced adoption of No-Till were reported as (Conacher and Jeanette, 1986):

- Inability of machines to handle crop stubble;
- Unsuitability of machines to local conditions;
- Poor seed depth control;
- High levels of damage and breakage;
- Poor back-up service and lengthy delays for repairs, and wide performance variations between machines

Problems associated with No-Till are recognised and many of them overcome (Carter, 1994; Baker *et al*, 1996). Similarly, the awareness among farmers regarding structural degradation of soils because of over-cultivation has also increased. Access to more information about No-Till is also now easier, therefore, farmers have started realising the importance of No-Till and its adoption may increase.

Advantages mentioned in section 3.2.2 suggest that several factors encourage farmers to adopt conservation tillage practices. Due to increases in the cost of machinery, fuel, and labour, these practices are needed in developing countries as well as in developed countries. The obvious problem in introducing these practices in developing countries is a lack of education and knowledge about these practices. Demonstrating comparable yield results to farmers may help and many efforts are underway to introduce conservation tillage practices in various parts of the world (Christian and Ball, 1994). A case study in Pakistan (Abbas *et al*, 1996) indicated that there were strong chances for its success in the rice-wheat cropping system if factors such as availability of No-Till equipment and chemicals were considered. However, Christian and Ball (1994), and Masse *et al*, (1994) reported that the economic limitations appeared more determinative in the evolution of soil tillage than any environmental issues.

The complexity of making a choice amongst various tillage techniques is evident from preceding paragraphs. Therefore, there has always been a need to ensure that more up-to-date information was available to extension agents and farmers to assist them in selecting the appropriate tillage methods under their farming conditions. It is anticipated that combining knowledge of how tillage affects the parameters and processes of crop establishment, would permit evaluation of different tillage systems. In the past, there have never been any clearly defined procedures for selecting a tillage system. It is envisaged that a computer-based expert system could be a useful tool for solving the complexity of tillage selection procedures (Clarke *et al*, 1990). This would enhance the quality of the decision making on this subject.

Chapter-4 Adoption of Agricultural techniques with special emphasis on Conservation Tillage

4.1 Introduction

Agricultural research findings are of little use if they are not adopted by farmers. An innovation diffuses in a social system through its adoption by individuals and as well as in groups (Ruttan, 1984). The decision to adopt an innovation, however, "is not normally a single, instantaneous act" (Jones, 1967). In the 1950s and 1960s agricultural scientists argued that the failure of modern technologies to spread was rooted in the conservatism and backwardness of the traditional farmers (Boef *et al*, 1993; Buttel *et al,* 1990). However, in the 1960s a number of researchers (Wilde, 1967; Mellor, 1966) observed that the failure of farmers to adopt a new technology was not the result of their conservatism, but emanated from inappropriate design of the technology for the farmer's ecological and socio-economic conditions. Researchers began to focus on the constraints influencing the farmer's perceptions and strategies, and sought to understand the rationale underlying farmer practices. By the 1970s social scientists were convinced that in fragile environments at least, the small-scale farmers would accept any strategy which would maximize their crop yield (Boef *et al*, 1993). Based on a study in Australia, Bardsley (1982) showed that farmers preferred information sources which could show the results of the new recommendations, and which had the knowledge of the economic consequences of the recommendations. Realizing the complexity of transferring technology, the need for an institutionalized form of multidisciplinary research was identified and as a consequence "farming system research" (FSR) emerged in the 1970's. Under FSR the researchers were expected to develop research methodologies and approaches which would tailor the needs of small-scale farmers (Hilderbrand, 1981; and Rhoades *et al*, 1987). In FSR the scientists emerged as a broker between farmers and agronomists, elaborating models of the small-scale farmer environment which could be incorporated into the development of appropriate technology designs (Boef *et al*, 1993). Feedback from farmers and its incorporation into the technology testing programs was also one important component of FSR (loc. cit.). Ashby (1987) reported that sometimes, farmers carry-out their own experiments and may select or reject any new technology they come across. Therefore, the close contact between farmers and researchers (under FSR) led to yet another new research model called, the *farmer-back-to-farmer* model. The concept of *farmer-back-to-farmer* was simply where ongoing evaluation of technology by farmers played an important role in influencing the process of any other new technology development (Rhoades and Booth, 1982).

Technological change is essentially an evolutionary process (Roger, 1983). It has also been a continuous, and largely an irreversible process which is always difficult to predict (Van Den Ban and Hawkins, 1988). These changes can only be met when socio-cultural, biological and political economic perspectives are combined consistently and logically (Amanor *et al*, 1993). Government regulations, taxation policies, investment priorities of entrepreneurs, consumer preferences, and environmental factors influence the direction of a technological change (loc. cit; Boef, *et al*, 1993). Governments normally seek two objectives from agricultural extension network systems (Van Den Ban and Hawkins, 1988). The first is to help farmers reach their goals, and the second is to change farmer's behaviour in order to reach government goals (loc. cit.). To achieve these targets, the authors recommended that an agricultural extension agent should understand:

(a) crop and livestock production

(b) farming as a business

(c) agricultural development process

(d) farmers and the way they learn

(e) rural society

Roling (1990) reported that no single agricultural knowledge information system can be developed for both low and high potential agricultural production systems. This chapter discusses the linkage between agricultural extension and agricultural research, various stages of an adoption process, and reasons for non-adoption.

4.2 The extension-research linkage

Van Den Ban and Hawkins (1988) reported Havelock (1971) describing the development of three models for the linkage between research and its introduction to the end users. These models were:

- **The Research, Development and Diffusion Model:** deals with basic research; applied research; development; and then its diffusion. This model is recommended for the industrial use. For example, development of a florescent lighting tubes must have passed through all these stages.

- **The Social Interaction Model:** stresses the diffusion of innovations. In this model it is assumed that innovations have been developed, and these are profitable for the end user. The mass media plays an important role in creating awareness which leads to adoption of such innovations.

- **The Problem Solving Model:** starts with the person who has a problem rather than research or the innovation. For example, a farmer needing to solve a problem will collect information either from the existing research findings, or from other farmers of the region. His/her research will give some indication of the income (losses) and risks expected from these alternatives. Based on this information, the farmer will then solve his/her problem. This model, however, is not very helpful in considering how farmers can reach a large number of other farmers facing similar problems.

An extension organization plays an important role in the latter two models. The major role in the second model is to diffuse research findings to the farmers, while the third model is to help farmers clarify exactly what their problem is and to find or to develop the information required for its solution. In the diffusion model extension agents act as an expert who teaches the farmer new knowledge, while in the problem-solving model they act as a guide and mentor to help farmers.

4.3 Various stages of an adoption process

Research studies have demonstrated the extensive delays that often occur between the time farmers first hear about favourable innovations and the time they adopt them (Van Den Ban and Hawkins, 1988). For example, it takes four years on average for the majority of mid-Western US farmers to adopt recommended practices (loc. cit.). Research workers have naturally been keen to find out what happens during this time. As reported in section 4.1, (Boef *et al*, 1993; Buttel *et al*, 1990) it was thought that people adopted innovations slowly because of their traditional or conservative attitude towards life. It was called 'individual-blame' hypothesis. Research among Latin American farmers has focused attention on the `system-blame' hypothesis which stated that it was not sensible for farmers to adopt ideas in their present situation, and a need to convert it to local conditions was essential (Van Den Ban and Hawkins, 1988). They believed that either the farmers did not have sufficient sources, or the power relationships in the society were such that estate owners, moneylenders, traders and others gained more profit from these innovations than the farmers themselves. Their study claimed that it was also possible that innovations were not available in remote villages or were sold in much larger quantities than a small farmer could use or afford. For example, the reason for reluctance of a small farmer in using fertilizer might not be the traditional attitude towards this innovation but the fact the farmer does not want to borrow money for it at high interest rates.

Farmers pass through several mental stages after the awareness of an innovation and before its adoption (Dasgupta, 1989; Byerlee and Polanco, 1986). They may skip one or several stages of the adoption process in reaching the adoption stage. Sometimes farmers may decide to adopt or to reject an innovation at any stage of the adoption process. In fact, they may also decide to discontinue a practice after initially adopting it either because of disenchantment with the innovation or because of the availability of a superior innovation. The following stages are often used in the diffusion process (Van Den Ban and Hawkins, 1988).

1. **Awareness**: first hear about the innovation.

2. **Interest**: seek further information about it.

3. **Evaluation**: weigh up the advantages and disadvantages of using it.

4. **Trial**: test the innovation on a small scale.

5. **Adoption**: apply the innovation on a large scale instead of old methods.

The following characteristics are important in analysing the relationship between an innovation and its rate of adoption:

1. **Relative Advantage:** Does the innovation enable the farmer to achieve their goals better or at lower cost than previously?

2. **Compatibility** with socio-cultural values and beliefs, with previously introduced ideas or with farmer's need.

3. **Complexity:** Innovations often fail because they are not implemented correctly. Some require complex knowledge or skills.

4. **Trialability:** Farmers will be more inclined to adopt an innovation which they have tried on a small scale on their own farms, and which proved to have worked better than an innovation that had to be adopted immediately on a larger scale.

5. **Observability:** Farmers learn much from observing and discussing their colleague's experiences. Their observations are often a reason to start these discussions.

The adoption and diffusion of an innovation is not simply a matter of economic profitability (Nagy and Sanders, 1990; Nagy and Zulifqar, 1993). Many farmers, to the surprise of extension workers, reject new concepts which had obvious qualities to be of economic benefit to them. Dasgupta (1989) reported that farmers even in the developed countries did not solely determine the decision to adopt or reject a practice recommended to them on the economic profitability. The perception of economic advantage of a recommended practice was also influenced by personal, situational, social or cultural factors (Dasgupta, 1989).

Differences between people who readily adopt innovations and those who play a waiting game are an interesting topic for investigation. Dasgupta (1989) described various characteristics of an adopter of new technology. Although there seemed no statistically significant association between age and adoption behaviour, the adopter tended to be middle-aged farmers rather than being young or old. The adopters had also a higher level of literacy and formal education than non-adopters. Other characteristics observed were:

- The size of holding owned and operated by adopters was larger than that of non-adopters.

- Adopters had a higher level of income than non-adopter.

- Adopters belonged to higher socio-economic status levels than non-adopters.

- Adopters had a higher level of cosmopolite orientation than non-adopters.

Van Den Ban and Hawkins (1988) reported that the process of adoption was also influenced by the farmer's attitude, values and their social structure. They quoted that the adopters were less oriented to the past in their values and attitudes than the non-adopters. Understandably, the level of motivation to achieve was higher among adopters than the non-adopters. Dasgupta (1989) observed that the adopters seemed more individualistic than the non-adopters.

Dasgupta (1989) reported a close relationship between the channels of communication used by farmers and their adoption behaviour. He observed that information flowed easily from farmers of higher socio-economic to those of lower socio-economic status and the mass media had an effective influence on both large and small farmers when they were equally accessible to both groups (loc. cit.).

4.4 Reasons for Non-adoption of an approved sound practice

Many different reasons are given by farmers as to why they have not adopted a particular technology or management practice. Particularly with environmental innovations, such as conservation tillage, adoption does not necessarily follow all stages mentioned in section 4.3. For example, benefits of No-Till may not be visible in short term field trials (Vanclay, 1986) and farmers may be cautious in committing themselves for any such management practice. In the context of No-Till, Vanclay and Lawrence (1995) outlined following reasons for non-adoption of a generally approved sound practice:

Complexity. In general terms the more complex the innovation, the greater the resistance to adoption. No-Till requires greater management skills (Crosson, 1981), thus the farmer's hesitance towards its adoption seems natural.

Divisibility. Divisibility allows for partial adoption. Farmers can adopt that part of an innovation that is consistent with other farming objectives. As, No-Till is about total new farm management (Crosson, 1981; Crosson *et al*, 1986) which is not divisible, they are less likely to be adopted.

Congruence - Incompatibility with farm and personal objectives. Farmers are more likely to adopt innovations that are compatible with other farm and personal objectives. As, mentioned above, No-Till is complex and indivisible, and it is also likely to bring major changes in the farm (like buying another drill or spraying equipment). Therefore, while converting to No-Till some new farm operations may not be compatible with other farm operations. In such circumstances the innovation is likely to be resisted.

Economics. The more likely an innovation will provide economic benefits, the greater the likely rate of adoption (Vanclay, 1992a). No-Till rarely provide direct economic benefits to the farmers right from the year one (Stonehouse, 1997, Stonehouse, 1995, Gray and Leiser, 1982), thus, these techniques are less likely to be adopted if farmers were to base their decision solely on economic criteria.

Risk and Uncertainty. Farmers may be concerned if the capital invested (e.g. buying a No-Till drill, or spraying equipment in case of conservation tillage techniques) in adopting the new technology will not result in any benefits. While farmers do not necessarily make conscious and sophisticated analyses of the degrees of risk in adopting technology, they are usually aware of the implication of particular choices. In cases of higher risk and uncertainty, farmers are not likely to adopt No-Till.

Implementation Cost - Capital Outlay. In addition to the economics of the innovation in terms of whether the innovation will increase profit, it is necessary to consider the capital required to adopt new technology. For example, No-Till may require capital outlay in the form of new machinery, seed, agro-chemicals, and earthworks. Arranging finance for these may not be very easy at times, thus adoption of the new technique is likely to suffer under such circumstances.

Conflicting Information. No new technology, especially that designed for conservation purposes, is free of debate about its applicability and effectiveness. Farmers receive information from numerous sources and those resources often contradict each other (Vanclay, 1992a). This can be one of the reasons for slow adoption of No-Till.

Loss of Flexibility. Farmers like flexibility because it means that they can change commodities in response to the market prices and climatic conditions. For example, perennial pastures may lock farmers into grazing, and No-Till may restrict the range of crops that can be grown and the rotation of those crops (section 6.13). Therefore, inflexibility discourages adoption of No-Till in few such cases.

Physical and Social Infrastructure. The lack of appropriate infrastructure in the region is a barrier to adoption of certain practices. For example, introduction of a new tillage technique may require an efficient and well informed agricultural extension facility, and if such infrastructure is not available, adoption of new techniques may be difficult. Social infrastructure also plays its role. For example, Vanclay and Lawrence (1995) reported that in the past decades, in Australia, many farmers have not regarded themselves to be in direct competition with their neighbours, sharing ideas, knowledge, and sometimes equipment. In another area of Australia, most farmers did not want to be the only one to undertake a new practice, or to grow a new crop (Vanclay and Lawrence, 1995). Introduction of new techniques in a such social structure is difficult. Thus, adoption must normally wait until there is a sufficient interest in the innovation to promote it on a wide-scale. Therefore, a supportive social infrastructure is necessary for wide spread adoption.

Environmental Perception. Research has established that farmers are likely to adopt environmental management techniques when, among other things, they consider themselves to be personally at risk from environmental degradation (Rickson *et al*, 1987; Vanclay, 1986). Thus, explanation of some background information may help farmers in realizing that they need to play their role for an improved environment which may be a step toward adopting a new technology. Failure to do so may result in less adoption or a slower adoption of the new technology.

4.5 Use of Computers in Introducing new Agricultural Techniques

Baigent (1981) predicted that the use of computers would greatly enhance the ability of the agricultural extension worker in providing an efficient farm advisory service. Currently, the farmers can make use of the latest information to select a profitable production technology, create optimal growth conditions for plants, crops, or animals, and decide when and where to sell the products (Plant and Stone, 1991). To get relevant information on a subject, a farmer may have to answer a few questions of an ES. Such task was previously entrusted to the mass media or the extension agent who used to visit the farm personally. Because of these new developments, Ezell (1989) foresaw that agricultural extension agents would in particular be affected and their future would depend on their ability to use computer technology. Fletcher and Deeds (1994) explained that with the advancement in communication through computers, web pages, the availability of computer-based expert systems, and above all the low cost of computers, it is possible that computer based expert systems may take the role of providing efficient farm advisory services (as predicted by Baigent in 1981). Many extension agents in industrialised countries now have computers for storing data and retrieving literature for use during extension seminars (Van Den Ban and Hawkins, 1988).

This study is also aimed to design an expert system to be used by extension agents seeking advice on whether to apply No-Till in a particular situation, and to disseminate knowledge on crop establishment to non-experts, farmers and to the extension agencies.

Chapter-5 No-Till Expert System

5.0 Factors affecting the choice of No-Till

The success of No-Till depends on factors mentioned in section 3.3. As mentioned in section 3.2.2, the principal incentives to the farmer considering adopting No-Till are the potential savings in labour, time and machinery cost (Christian and Ball, 1994). Among biophysical factors, soil and climatic factors are the most critical. Farm size, land tenure rights, slope, texture and drainage are the other important factors. Length of growing season, types of crops grown in the area also need to be addressed. Socio-economic and cultural factors also need due attention while making a decision whether No-Till should be adopted or rejected.

NOTE focuses on either choosing or rejecting No-Till under given situation. It has been applied to:

- Rice-Wheat and Cotton-Wheat systems in Pakistan

- Pasture over-drilling in New Zealand

Further developments in the NOTE will enlarge its scope for a wider range of tillage techniques. It is hoped that the use of this ES will be one of the cost-effective way of transferring researcher's expertise to provide decision support for farmers and extension agents alike.

This chapter discusses the importance of the technical, social, economic and the environmental factors chosen for designing the NOTE.

5.1 Technical

5.1.1 Soil texture

Knowledge of soil type is a critical determinant the selection of a tillage system (Lal, 1985; Lal, 1995). Soil texture, structure and drainage are important soil factors affecting the choice of tillage type (Lal, 1995). Knowledge of soil texture plays its role in determining how much water can be retained in the soil or how water moves downwards from the surface, how it moves up from the lower elevations or from the water table (Schulze, 1990). These movements in turn determine the moisture status and the way it affects crop growth (Ehlers *et al,* 1983, loc. cit.). Though, Riley *et al*, (1994) reported that the influence of soil type on crop performance with reduced tillage systems usually has been of minor importance, greater difficulties nevertheless have been reported on poorly drained, heavy soils than on well-drained, lighter soils (Choudhary and Baker, 1994, Riley *et al*, 1994). As, the reduced cultivation techniques were seen to be of greater potential benefits on heavy-textured and difficult to cultivate soils, in the late 1960s and early 1970s increasing attention was given to experimenting with reduced cultivation or No-Till on such soils (Allen, 1975). It was reported that many heavy soils, particularly those that did not shrink on drying, and had low infiltration and poor drainage were not suited to No-Till (loc. cit.). For example, (Riley, 1983; Riley, 1985) reported poor results after early sowing on silt soils in Norway. Alternatively, silt clay soils in Sweden have been among those for which conservation tillage practices have been most successful. Rydberg, 1982; and Riley *et al*, (1994) suspected that it might have occurred due to improved surface moisture relations and better rooting in the un-ploughed soils.

Lal (1985) developed a numerical rating system to assess soil suitability for No-Till. Figure 3 shows soil suitability for different tillage systems in relation to their texture. It must be noted that soils with similar physical characteristics may respond differently to tillage methods depending on the prevailing soil-moisture regime. Similarly, soils with similar moisture regimes may require different tillage because of variations in their physical properties. According to Lal (1986) friable, coarse-textured self-mulching, and structurally active well drained soils were likely to respond better to No-Till or other reduced tillage techniques than soils with massive structure or which were easily compactable. Conversely, No-Till has proven less effective on soils with poor internal drainage and those with compacted surface and subsoils (Anon., 1993).

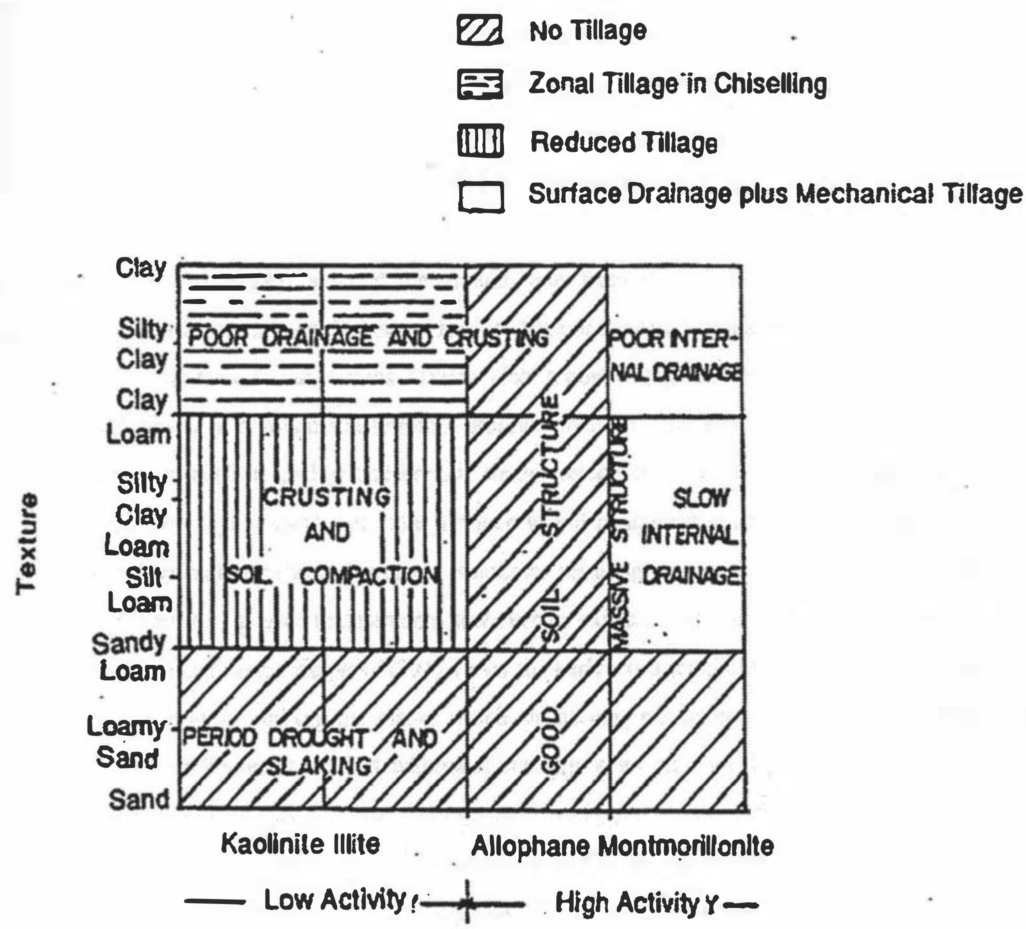

Figure 3 Soil suitability for different tillage systems in relation to texture
Source: Triplett and Sprague (1986). pp. 299.

5.1.2 Fertiliser requirement

Fertilisers have become indispensable for increasing food production. The nutrient status of soils in their native state depends on the composition of the soil parent material, and the nature and intensity of the various processes involved in soil formation. The increased application of chemical fertilisers is required to compensate, specially, the supply of nitrogen, phosphorus and potassium for good plant establishment. Tolba *et al*, (1993) reported that the use of fertilisers per hectare in the developed countries has been much higher than in the developing countries, although the rate of application in the latter countries has been rising fast. Knowledge of how much, when and where fertiliser has to be placed is of vital importance under any kind of tillage systems. It is an established fact that fertiliser requirements, particularly nitrogen is increased at least in the first few years of No-Till (Riley *et al*, 1994); although the amount varies from one situation to another depending on previous crops and on the general fertility level of the soil (Choudhary, 1983; Riley *et al*, 1994). Rasmussen and Collins (1991) also reported that successful No-Till requires development of a sound soil fertilizer program to meet yield goals and to accommodate changes in nutrient cycling and organic matter retention in the presence of high residue levels. One might expect that more nitrogen would be applied in order to compensate for any suboptimal physical or biological conditions resulting from such systems. On the other hand, over the long term, requirements may even be expected to decline as a result of organic matter accumulation. Kuipers (1991) views the early extra requirements of nitrogen as an investment in the soil organic matter which, in the long run improves soil structure. Once the new equilibrium is reached, additional nitrogen is not required (Kuipers, 1991). As far as, nitrogen uptake is concerned, Thomas and Frye (1984) reported that the actual nitrogen uptake by plants grown under conventional and No-Till did not vary except with crop yields. Therefore, they contend that if yields were identical there would be no difference in nitrogen requirements.

Efficient No-Till drills are now available that can place fertiliser near the seed, and help it to germinate and establish a good crop (Baker and Afzal, 1981). However, to achieve comparable yield results from No-Till, emphasis must be placed on the correct rate, timing and method of fertiliser application. For example, under Pakistani situations, Pakistan Agricultural Research Council, Islamabad, Pakistan recommended the following fertiliser dose for wheat cultivation under No-Till:

> "150-115-60 NPK kg/ha (All P and K with $1/3_{rd.}$N with second irrigation, and the remaining ($2/3_{rd.}$) N in Mid. January".

In agricultural terms, New Zealand is relatively a young country, and in many areas the intensity of land and fertiliser use has not been high (McLaren and Cameron, 1996). However, nitrogen stress in pasture occurs in New Zealand at different times during the year depending on local climatic conditions. Many New Zealand pastures, whether used for sheep, beef, dairy or hill farming show good responses to N fertiliser applications. The crop immediately following pasture can usually obtain sufficient N from the mineralization of the ploughed in grass and clover, and no fertiliser N is required. However, later crops, and those grown in a more intensive cropping system without pasture, normally require N fertiliser. Under suitable conditions wheat, maize and barley have all shown considerable yield increases with fertiliser N applications.

Phosphorus requirements by crops grown under No-Till were slightly greater than conventionally grown crops (Thomas and Frye, (1984). These requirements were greater only because of slightly higher yields with No-Till (loc. cit.). However, in soils, there are three factors that are affected by No-Till which in turn strongly affect uptake of phosphorus by plants. These are:

- **Soil temperature** under a mulched surface is generally lower than where a soil has been disturbed by conventional tillage. Thus, the lower temperature resulted in greater phosphorus requirements at seedling growth and development stage.

- **Soil water contents** are higher under No-Till, especially near the soil surface. Therefore it would be expected that under No-Till, the rate of diffusion of phosphorus would be higher than in conventionally tilled soil.

- **Fertiliser placement** is the third factor affecting phosphorus requirements. In conventionally tilled soils fertiliser was mixed uniformly at a certain depth, but in No-Till it is normally spread on the soil surface. Thus, because of the minimum contact with soil in case of No-Till, it was expected that fertiliser phosphorus would be available over a longer period than when it was mixed with the soil.

The behaviour of potassium in soils was not much different in No-Till or conventional systems (Thomas, 1986). When potassium was applied in soils under conventional tillage, it was usually ploughed or disced into the soil immediately after fertilisation. In subsequent years, it was mixed further as more tillage was done. During this time additional potassium was usually added, which resulted in a noticeable diminution of available potassium occurring below tilled area. When No-Till was practised potassium was applied to the surface of the soil only and the only movement that occurred was that due to leaching. But, according to Thomas and Frye (1984) the difference in potassium distribution has not shown any importance towards plant nutrition.

It is expected that with the introduction of newly designed No-Till drilling machines, the mechanism of placing the correct dose and the appropriate place is possible.

The farmers adopting No-Till should ensure that the correct amount of fertiliser is applied and that they possess the correct equipment to apply this dose.

5.1.3 Crop rotation

Crop rotation is one of the important management decision that affects tillage selection and consequently the crop yields (Lal *et al*, 1994). Studies have provided well-documented economic and environmental benefits of crop rotation (Anon., 1989). Crop rotations can affect soil aggregation, bulk density, microbial biomass, water infiltration and other soil properties (Papendick, 1994). It is of greater importance with No-Till than conventional systems, as it minimises problems associated with fungal diseases, and in many cases may also reduce weed problems (Riley *et al*, 1994). Many of the initial studies on No-Till concentrated on a form of sequential monoculture which over time presented various constraints to sustainable crop production (Carter, 1994). A conscious choice of crop sequences can allow a positive "rotation effect" as demonstrated by improved soil conditions, plant nutrition, root growth, and weed, pest, and disease control (Francis and Clegg, 1990; Crookston *et al*, 1991). For example, rotation of grain legumes with cereals tends to remove the differences in accumulation of nitrogen in the cereal grain previously found in No-Till and mouldboard ploughing comparisons (Carter, 1994).

A combination of crop rotation and No-Till has a positive effect on soil biological activities (Dick, 1992) which in turns maintains optimum soil and crop productivity in different soils and climatic zones (Cornish and Pratley, 1991). Olofsson and Wallgren (1988) reported severe yield reductions in a Swedish trial series when winter wheat was direct drilled either in monoculture or in rotation with barley. Similarly, Vyn (1988) and Raimbault *et al*, (1991) noted reduction in corn yield planted under No-Till following either red clover or fall rye. Lal *et al*, (1994) also reported similar findings. They observed that corn grain yields under No-Till since 1980 (after 20 years of continuous No-Till) have reached levels equal or greater than levels obtained for the mouldboard plough treatment. In their experiments, the corn grains yields associated with the corn-soybean rotation responded especially well to the continuous application of No-Till. These authors were not very sure, but they suspected that climate, changes in soil chemical, physical and biological properties, and improved, more disease-resistant corn hybrids were the possible reasons for this trend. Similar rotational effects were observed for soybean, when corn-soybean rotation gave the most consistently high yields (Edwards *et al*, 1988).

Unger (1984) and Unger and Wiese (1979) concluded that crop rotation was especially appropriate where water for irrigation was limited because the fallow periods between crops provided time for additional water storage in soil for use by the next crop. Crop rotation involving a winter and a summer crop, for example winter wheat and grain sorghum, were considered highly effective for controlling weed problems also in the USA (Unger and Skidmore, 1994).

Because of involvement of multiple years of studies and experiments, information on the interaction of rotation and tillage for different crops and in different climates and locations may not be easily obtainable (Lal *et al*, 1994), but the basic information is likely to be helpful when choosing or rejecting an appropriate tillage technique.

5.1.4 Weed and pest problems

A widely held view among scientists is that effective weed control is the most important single problem limiting acceptance of No-Till (in New Zealand) (Pers. Comm. C.J.Baker, W.R.Ritchie; Triplett and Worsham, 1986). Though, conventional tillage systems uproot weeds, sever their contact with the soil to eliminate weeds by desiccation or covering (Triplett and Sprague 1986), herbicides have now allowed farmers to relinquish this time consuming weed control practice under reduced tillage techniques. Though applications of various herbicides differ among species of crops and weeds, planting modes, soils, and climatic regions, but the objective remains the same, to encourage maximum crop growth by relieving competition without tillage (Triplett and Sprague 1986). Thus, the knowledge of successful weed control has always been one of the important component for those farmers who were keen to adopt No-Till. Commenting on the introduction of new herbicides for controlling weeds Harper (1957) wrote "for efficient long lasting weed control, ploughing should be avoided, surface tillage reduced to a minimum and weed seed which are formed should be left on the surface to be killed by spraying when they do germinate." Subsequent development of new herbicides in the United Kingdom and marketing of the contact herbicide paraquat in the United States opened new opportunities for No-Till production. Choudhary and Baker (1994) observed that post-emergence weed problems differed according to the type of crops planted in New Zealand. For example, a normal post-emergence selective herbicide treatment is recommended for grain crops grown under No-Till (loc. cit.). On the other hand, in forage crop establishment, some weeds make useful contribution to available feed and further control measures are not required. Thus, reasonable planning is essential for good weed control in New Zealand (Choudhary and Baker, 1994). For example, because a winter forage crop is often grown ahead of spring planting of a summer cereal crop, the choice of winter forage species and how it is managed can greatly influence the cost and effectiveness of the chemical weed and pest control required to establish the cereal crop.

East European researchers have also accepted that weed control was a vital component of the success of No-Till and that the application of agro-chemicals have played an important role in crop production (Butorac, 1994). Currently, their increased use have made such systems less attractive in environmental terms and this issue needs to be addressed according to local legislation of each region.

5.1.5 Straw residue management

Straw residue left on the surface from previous crop presents problems both at sowing and later in the growing season (Riley *et al*, 1994). In conventional systems the problem is solved by ploughing. In No-Till it is important that it is evenly cut (harvested) and distributed at the surface (Ehlers and Claupein, 1994). Problem arises when farmers have to keep allowance for decomposition of this straw to such an extent that it would not negatively influence the establishment of the subsequent crop. On the other hand, the high amount of uncut residue may also drastically reduce the performance of the seed drill, i.e., the uniform seed placement in horizontal and vertical directions (Ehlers and Claupein, 1994). In such case, straw in the proximity of the seed may present a physical barrier to moisture uptake under dry conditions or it may aggravate problems under wet conditions (Riley *et al*, 1994). Straw residue also causes a marked lowering of early season soil temperatures and there is also the possibility of an effect on the incidence of certain fungal diseases (Riley *et al*, 1994). Greater economic and management inputs and perceived risks associated with maintaining surface crop residues also limit the adoption of No-Till.

Ehlers and Claupein (1994) attributed the difficulty in management of residue as a key factors of low acceptance of No-Till in Germany. On the other hand, adoption of No-Till has also been affected in the UK, as the possibility of burning straw residue had been reduced vigorously by official regulations (Cannell, 1985). Nevertheless, management of straw residue is an important decision making component of No-Till.

5.1.6 Seeding technology

The use of correct seeding equipment is one of the critical factors in the adoption of No-Till. In such techniques a large amount of straw residue is left on the soil surface (see section 5.1.5), thus, the seed drill design must be able to prevent mechanical blockages, and be able to place seed into moist soil at appropriate depth (Dyck *et al*, 1990). Long-term trials at Lethbridge, Canada, have shown that differences among drills averaged over several years were small, but depending on the particular year and seedbed conditions, one drill may have advantage over another (Foster and Lindwall, 1986; Lindwall and Anderson, 1977). According to these authors, in dry conditions, hoe drills provided the most consistent performance and highest yields, and in the years when moisture conditions were more favourable and crop residue levels were not excessive, disc drills proved superior. This was probably because they caused less soil disturbance which resulted in less stimulation of weed growth (loc. cit.). Larney *et al*, (1994) suggested that besides considering features like the cost effectiveness, horsepower requirements, ease of maintenance of No-Till drills, following factors should also be considered:

- ability to cut through and clear heavy trash;

- ability of even penetration in hard soil conditions;

- good depth control for providing proper seed placement;

- ability to ensure a firm seed-soil contact.

Under predictable conditions, a drill can be designed to meet the specific conditions. For example, Throckmorton (1986) described the concept of Aitchison[1] No-Till drill opener in New Zealand where rather than depending on heavy weighting for coulter penetration into soil, the Aitchison drill was fitted with narrow pitched blades on each side of the opener. Similarly, the development of new seeding technology (high-clearance hoe drills, No-Till drills, air seeders) in the 1980s have provided drills that could effectively penetrate heavy crop residue and more compact soils to place seed and fertiliser at appropriate depth in moist soil.

Fertiliser placement mechanisms attached to a planting machine is also important in No-Till. The study at Lethbridge and Vauxhall, Alberta (Carefoot *et al*, 1990) suggested that fertiliser nitrogen should be placed below the straw mulch layer to minimise nitrogen immobilisation. Other studies at Massey University, Palmerston North, New Zealand (Choudhary, *et al,* 1985; Baker and Afzal, 1986) suggested that seedling establishment was related to the accuracy of seed placement within the seed groove, and positive responses to

1 Mention of trademarks or vendors do not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

seedling emergence were observed when granular nitrogenous fertilizers were separated from the seed horizontally by 10 to 20 cm as compared to vertical separation by the same distance. Therefore, a drill having the ability to place seed and fertiliser separately can be considered as an important factor in the adoption of No-Till.

5.1.6.1 Suitability of Drills in Various Situations

Soil type, the quantity and distribution patterns of plant residue on the soil surface, and chemical or fertilizer application methods have a major influence on the design of No-Till

Table 7 Suitability of drills in different soils and stony conditions

	Soil texture						Stony condition			
✓ = suitable O = marginal X = unsuitable	Light (Sand pumice)		Medium (loam)		Heavy (clay, heavy silt)		Medium (orange-turnip sized)		Large (football sized)	
	Wet	Dry	Wet	Dry	Wet	Dry	stone amongst the soil	soil amongst the stones	stone amongst the soil	stone amongst the stones
Light drills with spring tine legs and limited depth control										
Winged openers	✓	✓	✓	✓	✓	✓	✓	✓	X	X
hoe openers	O	O	O	✓	X	✓	✓	✓	X	X
Conventional drills with floating dragarms										
dished disc openers	✓	O	✓	O	✓	X	✓	O	X	X
hoe openers	✓	O	O	✓	X	✓	✓	✓	X	X
Heavy duty direct drill with floating drag arms										
triple disc openers	✓	✓	✓	X	X	X	✓	O	O	O
hoe openers	✓	O	O	✓	X	✓	✓	✓	O	X
Heavy duty direct drill with parallel floating drag arms										
winged openers/notched disc	✓	✓	✓	✓	✓	✓	✓	X	✓	X
Power till drills										
rotary strip/fixed cutting heads	✓	O	✓	✓	✓	✓	O	X	X	X
rotary strip/floating cutting heads	✓	O	✓	✓	✓	✓	✓	X	X	X

Table 8 Suitability of drills with different surface conditions and levels of surface roughness

	Residue (trash)					Surface roughness			
✓ = suitable O = marginal X = unsuitable	bare soil, short pasture cut/forage crop stubble	standing stubble (baled cereal)	laying residue and tailings (cereals)	dense hi-country browntop	dense tussock	smooth	hoof pugged	embedded boulders or timber	rough (wheel track etc)
Light drills with spring tine legs and limited depth control									
Winged openers	✓	✓	X	O	X	✓	✓	X	X
hoe openers	✓	✓	X	O	X	✓	✓	X	X
Conventional drills with floating drag arms									
dished disc openers	✓	✓	✓	O	X	✓	✓	✓	O
hoe openers	✓	O	X	O	X	✓	✓	✓	O
Heavy duty direct drill with floating drag arms									
triple disc openers	✓	✓	✓	X	O	✓	O	✓	O
hoe openers	✓	O	X	O	X	✓	✓	X	O
Heavy duty direct drill with parallel floating drag arms									
winged openers/notched disc	✓	✓	✓	✓	O	✓	✓	✓	✓
Power till drills									
rotary strip/fixed cutting heads	✓	✓	O	✓	✓	✓	✓	X	O
rotary strip/floating cutting heads	✓	✓	X	✓	O	✓	✓	O	✓

Table 9 Chemical application features of overdrilling machines

	Groove shape:	Competition control:			Covering achieved by:		Fertilizer application:		Granule (pesticide) box
✓ = suitable O = marginal X = unsuitable	V or U or ⊥	Band spray	(Soil chopping	Soil bursting or press	Own wheels	Harrows separate operation	Mixed with seed	Placed in separate band	
Light drills with spring tine legs and limited depth control									
Winged openers	⊥	O	X	X	X	✓	O	X	O
hoe openers	U	X	X	✓	X	✓	✓	X	X
Conventional drills with floating drag arms									
dished disc openers	U (wide)	X	X	✓	X	✓	✓	X	X
hoe openers	U	X	X	✓	X	✓	✓	X	O
Heavy duty direct drill with floating drag arms									
triple disc openers	V	X	X	X	✓	X	✓	X	O
hoe openers	U	X	X	✓	O	✓	✓	X	O
Heavy duty direct drill with parallel floating drag arms									
winged openers/notched disc	⊥	O	X	X	✓	X	X	✓	✓
Power till drills									
rotary strip/fixed cutting heads	U (wide)	X	✓	X	✓	X	✓	X	O
rotary strip/floating cutting heads	U (wide)	X	✓	X	✓	X	✓	X	O

drills (Choudhary and Baker, 1994). For example, a light drill with spring tine legs and limited depth control may be suitable for light (sand pumice), medium (loam) and heavy (clay, heavy silt) soils. But, the same drill is not suitable if such soil contains large stones. However, an heavy duty drill with parallel floating drag arms may be able to work in a soil having large stones. Choudhary (un-published data) summarized the suitability of various drills in different soils (Table 7), surface conditions (Table 8) and their chemical application features (Table 9). These tables are the essence of experience of many years on No-Till.

5.1.7 Soil moisture

Tillage practices influence available soil moisture contents throughout the growing season (Triplett and Sprague 1986). In conventional tillage practices, moisture loss occurs because an increased area is exposed to the atmosphere that allows greater penetration of wind (Ojiniyi and Dexter, 1979). But, once rainfall occurs, greater recharging capabilities have also been reported in the tilled soils (Campbell and Akhtar, 1990). However, successful No-Till is characterised by its ability to conserve soil moisture by decreasing evaporation losses because of the residue cover in place (Triplett and Sprague 1986).

There have been reports that use of No-Till has increased soil water storage during non-cropped periods and thus, subsequent crop yields were increased (Unger, 1984). Similarly, in the semi-arid regions, effective maintenance of surface residue was considered essential to conserve water and obtain favourable crop yields with No-Till (Lal, 1991). Triplett and Sprague (1986) however, reported lower crop yields due to excessive soil water contents under No-Till in medium to heavy-textured soils because of poor aeration and slow soil warming. Keeping this in view, Triplett and Sprague (1988) recommended that No-Till was usually not suitable for poorly-drained soils as slow warming of soil may have been one of the factors affecting germination of the seed. Earlier, Griffith *et al*, (1973) reported that on well-drained soils where moisture stress can cause reductions in grain yield, No-Till generally produced equal or greater grain yield than conventional tillage provided equal plant densities and adequate weed control were applied. Baker *et al*, (1996) commented that "A dry untilled soil has more potential to germinate seeds and emerge the seedlings than a dry tilled soil; but very few No-Till openers are capable of harnessing that potential." In untilled soils a matter of a few days either way may make the difference between successful crop establishment or failure. Thus, knowledge of available soil moisture is valuable when selecting a tillage system.

5.1.8 Soil slope

With the increase in slope the choice of tillage system becomes more limited. Variable slopes tend to create complex soil profiles (Sojka and Carter, 1994) and the fields with greater slopes (>20%) may create problems in operating certain agricultural implements (Pers. Comm. Choudhary). In such fields the farmers are confronted with problems of managing various soil types within one field. For example, soil drainage and water management could be a difficult task on almost level and slowly permeable soils. However, on nearly level or gently sloping permeable soils, tillage could provide better conditions and may also effectively conserve the soil and water resources (Sojka and Carter, 1994). Allmaras *et al*, (1980) reported that on slopes of less than 12%, tillage systems and residue management alone could control erosion, and for inclines of 12 to 20% slope, the slope has to be interrupted through terracing to control soil erosion. Sojka and Carter (1994) suggested that for slopes greater than 20%, even combining the approaches of reduced-tillage, No-Till, or terracing would still result in soil losses above tolerance limits. Earlier Olofsson (1993) also reported that in too steep, wet, or stony areas, mouldboard ploughing is not feasible and No-Till is the alternative for pasture establishment in such areas. Thus, knowledge of the soil slope was considered as one of the factors while designing NOTE.

5.2 Social

5.2.1 Management strategies

Conventional tillage systems are more forgiving and repairable. For example, "mechanical weeding" can be re-done if the first operation has not been successful. On the other hand, Conacher and Jeanette (1986) reported that the success of No-Till is dependent on the managerial expertise of farmers. Earlier, Crosson (1981) found the literature virtually unanimous in asserting that No-Till required more skilful management than conventional tillage systems. In No-Till, the failure of an operation (say spraying or drilling) was usually not obvious until it was too late. Then at that stage it was not easily repaired or hidden. Unfortunately, the increase in management skill is not quantifiable (Crosson *et al*, 1986); however, it is directly related to production cost, and therefore is a key component of an evaluation of the economics of No-Till. The farmers who attempt reduced-tillage techniques, especially No-Till, without requisite skills encounter higher costs per unit of output (loc. cit.). Therefore, they may give up the attempt or invest money and time in learning the new skills. An agriculture extension network can be of great use under such circumstances (see section 5.2.3).

5.2.2 Other social aspects

Cultural traditions and production systems affect farmers' perceptions of their land and their decisions on its use (Chisholm and Dumsday, 1987). Personal factors may also influence the decision making process of a farmer. It is a common knowledge that a farmer may term a poor outcome from conventional tillage as a "bad luck", whereas failures with new techniques are attributed to the failure of the new system (Choudhary and Baker, 1994). Experience, knowledge, conceptual skills, and goals of the decision maker help to form attitudes and beliefs towards any new approach (Chamala and Keith, 1987). Apart from the soil and climatic constraints to the adoption process of new agricultural technologies, many farmers may still be reluctant to change from existing methods because of the fear that they may have to learn new methods of crop production (Steed *et al*, 1994; Crosson *et al,* 1986). However, once farmers are convinced of more favourable outcomes from the new technique, it is highly likely that they will not be reluctant to adopt them. A study in Australia showed that Australian farmers responded most favourably to new technologies when these were easy to use, inexpensive and promised short-term profits (Donald, 1970). With particular reference to No-Till, ignorance of problems to continuous tillage techniques may act as the first barrier to introducing No-Till. Even if aware, Napier *et al*, (1991) attributed "land tenure" as another social factor which may impede the change farmers may have in mind. They argued that "land operators" would not invest in soil conservation practices that required investment of the capital for buying new machines. The same may also be true for low land-holding or poor farmers who have been unable to invest in conservation tillage practices. Thus, study of the local social environment is one of the essentials in recommending a change from the existing tillage practices.

5.2.3 Technology transfer

Research findings and other farmers' experiences help farmers to achieve their goals more effectively. Agricultural extension services are expected to provide effective linkages between farmers and agricultural research findings for transferring new technology (Van Den Ban and Hawkins, 1988). According to Thomas *et al*, (1984) transfer of new technology will be accepted roughly in accordance with its effect on financial return to farmers. Van Den Ban and Hawkins (1988) reported that large farmers often adopt modem technology sooner than small farmers because of their ability to bear greater risks.

The change to No-Till has been slow but steady (Steed *et al*, 1994). Research and extension programmes that have demonstrated the benefits of No-Till technology have been a vital element of the adoption process (Butorac, 1994). Many information regarding No-Till has become available in recent years, and satisfactory systems are now available for many crops to grow under No-Till (Unger and Skidmore, 1994). These techniques, when properly implemented, have the potential to greatly reduce soil erosion and improve water conservation (loc. cit.). Unger and Skidmore (1994) further reported that this potential, along with the growing emphasis on the protection of the environment, should lead to greater adoption of No-Till. Major advances in equipment suitable for crop production by No-Till (such as development of suitable No-Till drill) will provide a better environment for its adoption. In addition, strong education and demonstration programs are also recommended to apprise producers of No-Till (Unger and Skidmore, 1994). However, it must be ensured that the agricultural extension system for introducing No-Till should be able to match local soils, crops, pests, climate, and equipment.

In the context of No-Till, the technology is likely to be accepted only if it makes a sizeable difference in farmer's income (Vanclay and Lawrence, 1995). Therefore, it is important that No-Till be tried on the crops that are more important to farmers. Keeping the importance of wheat, rice, and cotton in mind, the design of the NOTE was initially restricted to these crops in Pakistani situation, while pasture-over-drilling and cereal crops were considered in the New Zealand situation.

5.3 Economic aspects

Most farmers operate under constraints with respect to capital, land, and equipment resources (Unger and Skidmore, 1994). Farmers try to manage resources to meet their immediate as well as the long-term needs. To achieve these ends, they generally select crop production options that involve lower risks. Because No-Till is relatively new, farmers may avoid using such practice and continue to use the practices that have proven adequate through experiences. As mentioned elsewhere, (section 5.1.6) adoption of No-Till may also require the purchase of new or different equipment, and the farmer may be reluctant to invest, unless there is little or no risk involved with respect to meeting these urgent needs (Unger and Skidmore, 1994). Thus, economic evaluation of a farm by an expert becomes an important factor in such circumstances.

Ploughing alone represents about 40% of the total time required for traditional tillage and sowing (Conacher and Jeanette, 1986). Therefore, reduction in ploughing frequency, and the ploughing depth under No-Till can create opportunities of larger savings in fuel cost and machinery maintenance. Savings are also made in time, labour and machinery investment. Danfors (1988) reported that No-Till can provide an overall saving of 60-75% in labour requirement, even when extra spraying is necessary. Therefore, major advantages have clearly been shown for No-Till, especially when long-term equipment costs and depreciation were considered in the cost-benefit analyses (Conacher and Jeanette, 1986, Danfors (1988). However, when only short-term costs and returns were considered, No-Till is sometimes less economical because the cost of chemicals was high (Carter, 1994). Marra and Ssali (1980) also reported that No-Till became uneconomical relative to conventional tillage in places where perennial weeds were a problem, as these weeds were not adequately controlled even with larger amount of herbicides application. In such instances the economic disadvantage of No-Till may become significant and its adoption is unlikely. Role of extension agents under such situations become more important in assisting farmers for choosing an economic viable tillage technique.

5.3.1 Crop yields

Crop yield can be examined as a technical as well as an economic factor. Farmers' livelihood depends on the total production. If conversion to new tillage techniques will result in lower or uneconomical yields, then obviously the farmer will be reluctant to make the change. Several investigations have shown that crop yield is not necessarily lower with No-Till as compared to conventional ploughing (see section 3.3.3). During the course of time soil structure also improves and the farmer may also develop improved management techniques. Therefore, it is not surprising that yield of crops sown with No-Till may increase over time.

Choudhary and Baker (1994) reported that crops grown by conservation tillage methods often appeared smaller, and sometimes even stunted, in the early stages of growth, but this difference usually diminished at later stages. They have quoted Malhi and Nyborg (1990) stating that "in untilled topsoil, fertility remained concentrated at the surface and is not mixed as in tilled soils," thus raising the need of new spreading and distribution requirements of fertiliser during the entire crop growth period under conservation tillage techniques. In New Zealand for example, nitrogen is usually applied 2 to 4 weeks after sowing to give timely boost to tillering in autumn and growth in spring and early summer. This also avoids accelerating the growth of the competing resident species at the expense of the early development of the introduced seedlings (Choudhary and Baker, 1994). As a result, these authors reported that when fertiliser was placed below or beside the seed in No-Till soil (Baker and Afzal, 1986) and using the Cross Slot™ opener, yield comparisons between the tilled and the untilled soils were identical. Further, Janson (1984) also reported similar yields between tillage and No-Till (Table 10). In short, most researchers in New Zealand agree on a point that pasture yields under No-Till is very much comparable with conventionally tilled crops, and that these researchers have now raised the potential biological reliability of this technique to a higher level than that achievable under conventional tillage (Choudhary and Baker, 1994). Similarly, research in Pakistan (Aslam *et al*, 1989) have shown that No-Till plots had a yield advantage over tilled plots when these were planted soon after rice harvest and before the tilled plots (see section 6.5 for further details). Therefore, comparison of crop yields seems an important factor when considering a tillage technique. NOTE has incorporated this factor in its design.

Table 10 Crop Yields (t/ha) under two tillage systems from a six-year crop rotation

Year	(Crop)	No-Till	Conventional Tillage
1	(Linseed)	3.4	3.1
2	(Wheat)	5.47	5.25
3	(Clover)	0.30	0.30
4	(Wheat)	5.31	5.42
5	(Peas)	3.81	4.04
6	(Barley)	6.28	6.19

5.4 Environmental aspects

Most agricultural practices contribute to soil erosion, substantial negative effects on air and water quality and environmental degradation (Beke *et al*, 1989; Larney *et al,* 1994). Environmental issues have become more important in recent years, particularly with respect to chemicals in the environment. The pressure of producing more food to keep pace with the growth in population is aggravating this problem. Awareness of the problem has led researchers to point out the scenarios which are threatening the environment. Severe environmental problems associated with food production practices are summarised here under (Sundsbø, 1991):

1. Increased use of fertilisers

2. Intensification of livestock farming

3. More pronounced use of monocultures in arable farming aggravating the risk of erosion and increasing the demand for pesticides

4. Escalating the consumption of fossil fuels in agriculture

A constructive contribution in curtailing environmental problems can be achieved by finding solutions that do not lead to a fall in production (Sundsbø, 1991). Therefore, new production technologies must gain a better insight into the links between agricultural machinery, soil, and plants. No-Till provides one such platform from where soil structure degradation, and soil erosion can be controlled.

Carter (1994) described that the most obvious advantage of No-Till is its role in minimising the risk of erosion. In some cases shallow tillage has been shown to reduce erosion to about one half to two third by comparison with conventional tillage. However, the use of chemicals in No-Till has become an environmental issue (McEwen and Miller, 1987). A survey in Canada for example, indicated that the majority of Canadians were very concerned about the impact that agricultural practices have on water quality and more specifically about the increased dependence on pesticides (Anon., 1989). Carter (1994), predicted that wide spread adoption of No-Till may be limited because of its apparent increased dependence on pesticides. This view was strengthened by literature that confirmed that the potential negative environmental effects associated with pesticides used in No-Tillage were more serious than the sustainability concerns associated with the conventional tillage systems (Conacher and Jeanette, 1986; Larney *et al*, 1994). In other words, sometimes, the side effects of the potential cure for soil degradation were much more damaging than the problem itself. Thus, it is vital that the effects and fate of applied pesticides be monitored and well documented to ensure that recommended soil conservation practices were environmentally sustainable.

5.4.1 Legislation

Legislation provides legitimate basis for action and binds communities under international norms on the basic issues of environmental protection. There has been a major evolution of environmental laws in the industrialised countries from 1970 onward. United Nations Conference on Environment and Development (UNCED) held in Rio De Janeiro, Brazil, in June 1992, provided fundamental guidance, and has created a new dimension to future international action in the field of environmental laws (Philippe, 1993). For example, Environment 2010 Strategy of New Zealand Government now recognises the risks to the sustainable management of the quality and quantity of waters and the need for promoting integrated water and land management (Ministry of the Environment, 1995). The U.S. Department of Agriculture farm program requires that a certain amount of crop residue be left on the soil surface to mitigate erosion (Schueller and Stout, 1995). However, sustainable agriculture is not simply a matter of adopting environmentally sound practices

(Tolba *et al*, 1993), it is a matter of changing the attitudes of society, and legislation can play its role enforcing the change.

Enhancement and maintenance of soil productivity is essential for the sustainability of agriculture and to meeting basic food needs of a rising population. World soil resources are finite and it is believed that all potentially cultivable land has already been brought under cultivation (Lal and Stewart, 1995). Thus, future increases in food production have to come from intensification of cultivation on existing lands (loc. cit.). Therefore, the tremendous pressure on soils and environment by the industrial as well as agricultural expansion has created a new burst of questions. The intensive use and misuse of soils, water, and air resources have augmented the hazard of declining soil productivity. The use of fertilizers, insecticides, and herbicides has expanded tremendously. These trends have resulted in an increased sense of awareness of environmental issues(Tan, 1994). Due to this increased public interest and concern, legislative rules are framed so that agricultural production should be sustained without further damage to the environment.

5.4.2 Ground water contamination

Agricultural activities are the largest user of water in the world, accounting for two-thirds of the total fresh-water in countries from which data are available (Ongley, 1996). Agricultural production processes generate residuals such as manure, fertiliser, pesticides, and soil particles, which can contaminate both ground and surface water. Whether or not the application of fertilisers, pesticides, and herbicides become sources of contamination depends on changing hydrogeologic conditions, application methods, and biochemical processes in the soil.

Adoption of No-Till requires more application of herbicides than used in conventional tillage systems, thus more care is required while changing from conventional tillage practices to No-Till. Generally, when applied according to manufacturer's directions, within safe limits, and according to other acceptable practices, most commonly used herbicides pose no serious threat to the environment (Conacher and Jeanette, 1986). However, some herbicides degrade slowly and are transported by water or by soil that erodes from application which results in ground water contamination. Interestingly, Unger and Skidmore (1994) stated that transport of herbicides is less under No-Till than conventional conditions. They have explained that this is because water and soil movement across the land is less with No-Till, thus there is less movement of herbicides. However, they feared that this phenomena may be reversed in chemical application through fertilisers as No-Till requires additional fertiliser. Ground water quality laws deal with both the prevention of ground water contamination and the assigning of responsibility for ground water protection or clean-up and legal liability for damages where contamination has occurred. Thus, the knowledge of such legislation is helpful when converting from conventional tillage practices to No-Till.

5.4.3 Soil erosion

A principal advantage of using No-Till is soil erosion control (Lal *et al*, 1994). Regions with highly erodible soils, sparse vegetation, strong winds, and dry climate having occasional intense storms are prone to the highest erosion losses (loc. cit.). Physical activities such as removing vegetation, tilling or disturbing soil also intensify rate of erosion. Erosion problem is considered a widespread and costly problem which affects and disturbs agriculture, transportation routes, water supply and storage and urban development (Gray and Leiser, 1982). It is essential that farmers are aware of their role for rehabilitation of land against erosion.

Vegetation offers the best long-term protection against surface erosion by (i) binding and restraining soil particles, (ii) filtering soil particles out of runoff, (iii) intercepting raindrops, (iv) retarding velocity of runoff and, (v) maintaining infiltration (Gray and Leiser, 1982). No-Till is also characterised by their ability to reduce soil erosion, Data complied by Skøien (1988) shown a one half to two thirds reduction in erosion when shallow tillage was applied in comparison with conventional tillage. Tyler *et al*, (1994) also confirmed these results. Therefore in some countries, such as in Norway, where erosion risks are greater due to combination of topographic and climatic factors, government subsidies have been introduced for farmers who refrain from autumn ploughing on erosion-prone land (Riley *et al*, 1994).

No-Till has proven advantages in soil erosion control. Therefore, once farmers become well aware of the erosion problem, it is much easier for an extension agent to convince them for to adopt No-Till.

5.5 Summary

Sections from 5.1 to 5.4, explain that changes in a specific situation may change the specific recommendation for tillage. For example, the soil type, its topography, climate, crop, and the local legislation contribute toward the final choice of tillage. Therefore, farmers and agricultural extension workers need accurate information on what tillage system will work under particular field conditions. This information must be site specific and in a format that is useful and accessible to the farmer. Utilizing experts to solve the tillage selection problem can enhance the quality of the decision making. Although research on No-Till is on-going, and there is no clearly defined procedure for selecting a tillage system, the NOTE can assist in tying together the knowledge and current information to arrive at an acceptable decision.

5.6 Description of Kappa-PC

A shell, named Kappa-PC[1] was used for designing the NOTE. As described in section 2.5, an expert system has the following three components:

1 Mention of trademarks or vendors do not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

a. Development of core structure

b. Expansion of the knowledge base

c. Design of the user interface

Once the problem is identified, the knowledge engineers' next task is to select a suitable tool for building the proposed ES. A person who is not familiar with the computer programming languages normally chooses a suitable shell for building the ES (see section 2.5). For this project, two shells were considered:

- Initially a VP-Expert shell was considered for use but later discarded because of its limited capacity in its inference engine to handle large number of rules, and lack of support for long-term use.

- Kappa-PC was subsequently selected because of its higher capacity of handling rules. Other advantages included its being "windows" based and user-friendly program. A monochrome screen for colour graphics presentation with resolution equal or above 640x350 were the only other requirements.

5.6.1 Description of NOTE

NOTE contains and recognises commonly known values of various variables. It starts by asking the user "Please choose the country you are operating from" (Figure 4). Two choices (New Zealand, and Pakistan) appear on screen (Figure 5).

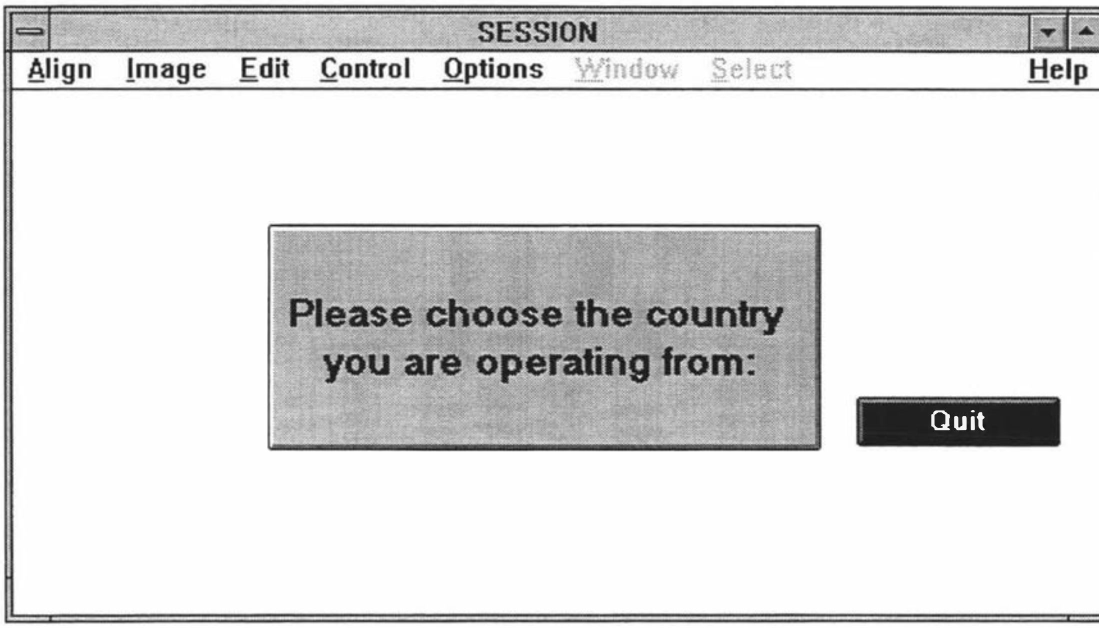

Figure 4 NOTE starts from asking "Please choose the country you are operating from"

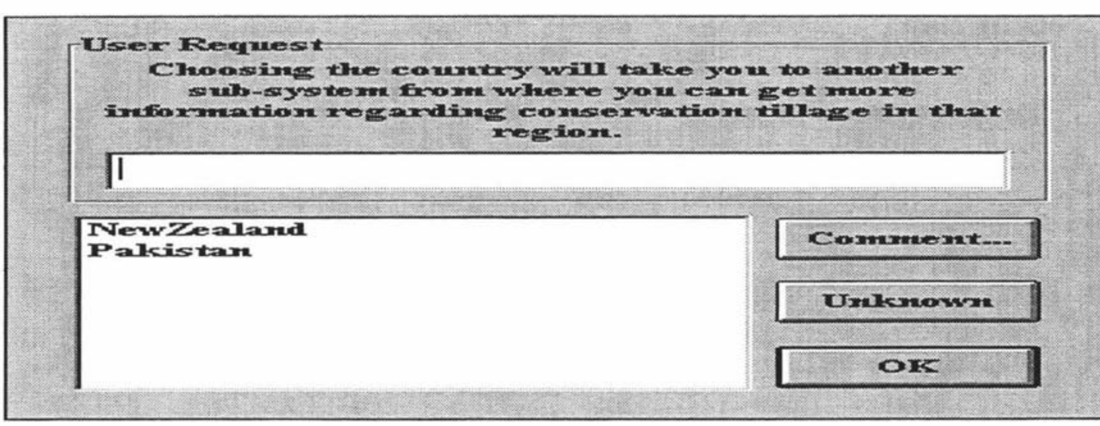

Figure 5 Two choices (New Zealand, and Pakistan) appearing onto the screen

Once the choice is made, the respective portion of NOTE prompts onto the screen. For example, if the user enters "New Zealand", a file named as NZ.kal is executed and Figure 6 appears.

Figure 6 **Once a choice about the country is made, Kappa executes the respective portion of NOTE.**

The user is then asked to choose the standing (or previously harvested crop) in the field (Figure 7). Once this choice is entered, NOTE brings a screen as shown in Figure 8.

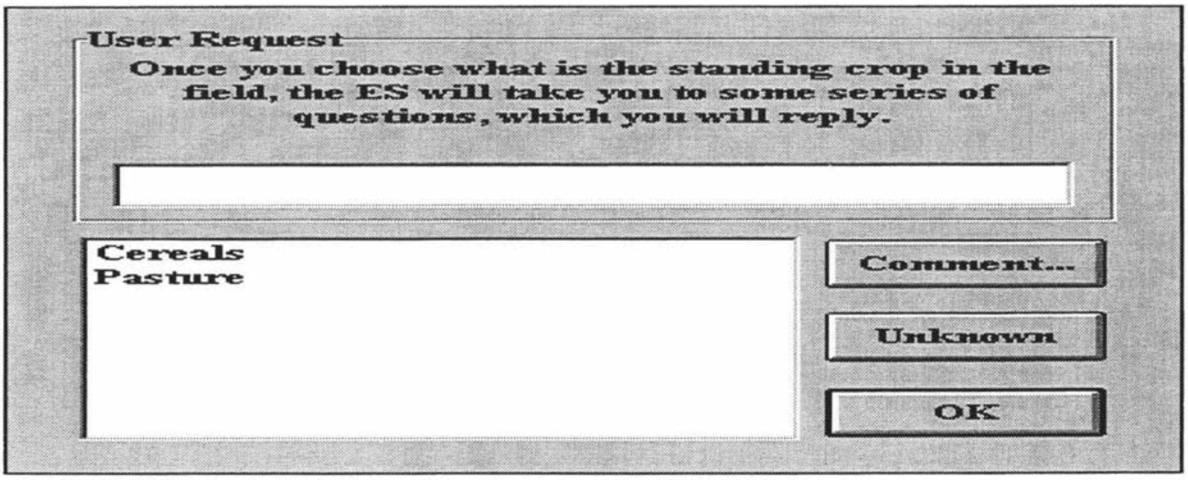

Figure 7 **NOTE asking about the standing (previously harvested) crop in the field.**

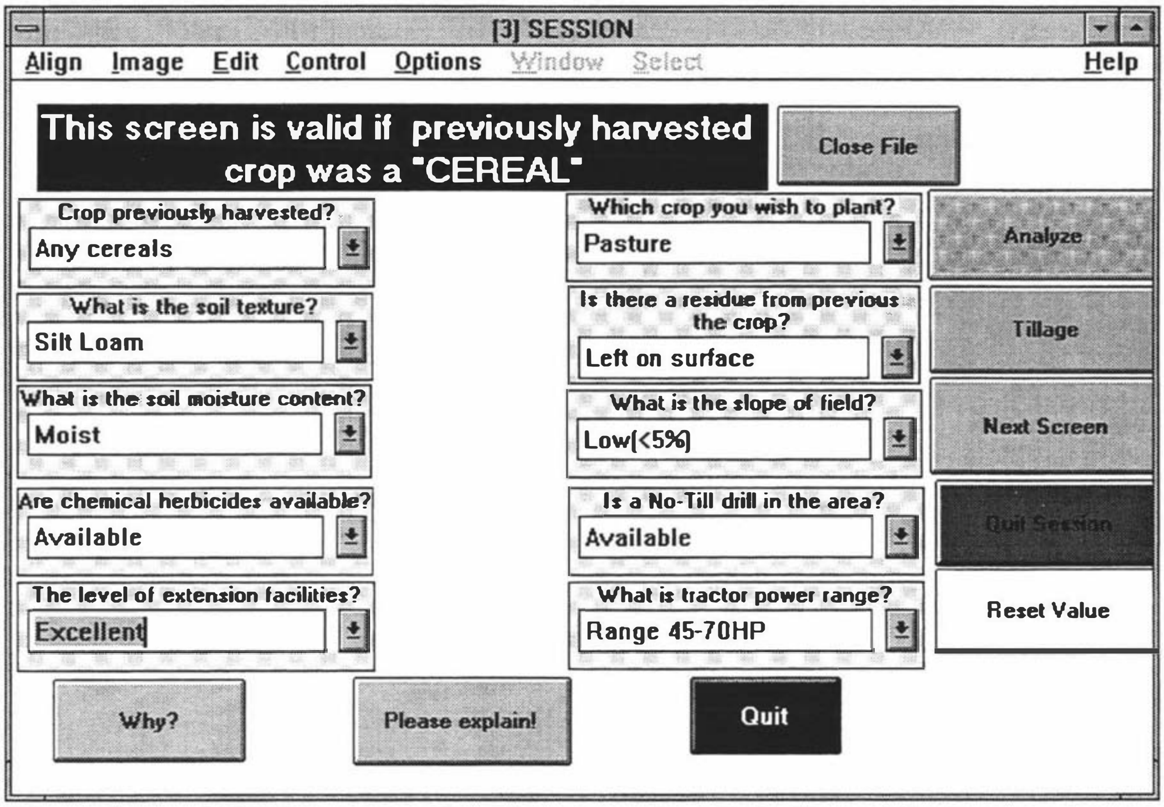

Figure 8 NOTE executing the relevant portion of the Expert System

The user is then required to enter values in the appropriate dialogue boxes. These boxes contains question like:

- Which crop you have previously harvested?
- Which crop you wish to plant?
- Is there a residue left from the previous crop?
- What is the soil texture?
- What is the soil moisture content?

- What is the slope of the field?

- Are chemicals herbicides available?

- Is a No-Till drill available?

- What is the tractor power range?

Data is entered in the dialogue boxes by picking and clicking the mouse. For example, when asked for the soil slope, the following three choices appear in the dialogue box:

1. Low(>5%)

2. Medium(5-12%)

3. High(>12%)

Once the values are placed in the dialogue boxes, the user should then press the button called "Analyze". The inference engine of NOTE evaluates all rules either by forward chaining process (see section 2.6.1) or backward chaining process (see section 2.6.2) (Figure 9) and a recommendation is made (Figure 10).

Finally, NOTE asks the user to enter the recommendation in the next dialogue box (Figure 11).

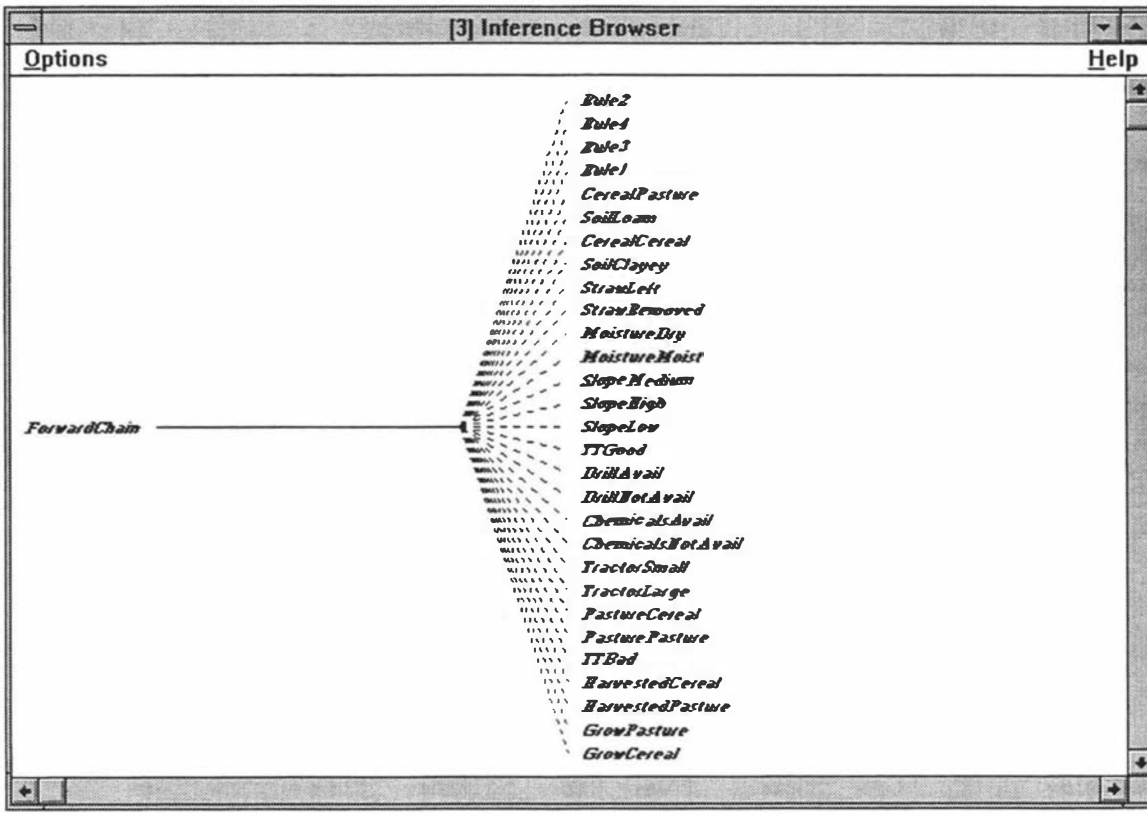

Figure 9 **Inference engine reading the rules in NOTE**

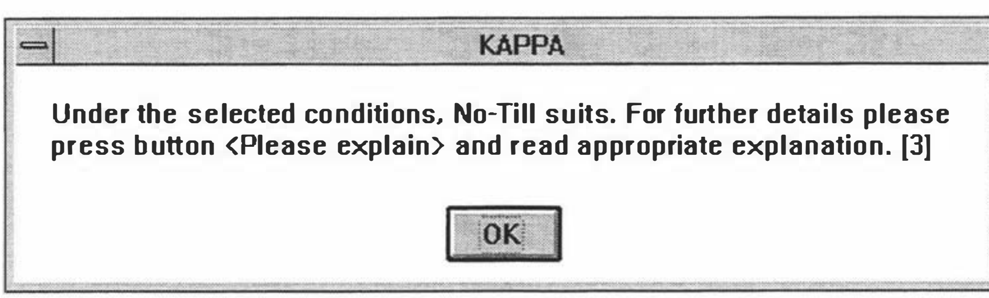

Figure 10 **NOTE showing a recommendation once the button "Analyze" is pressed.**

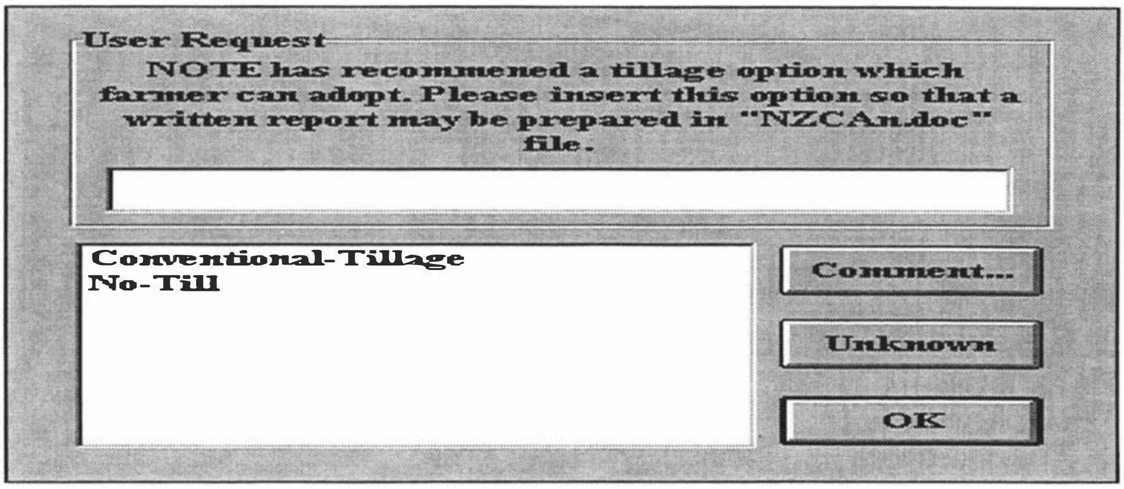

Figure 11 The dialogue box requesting to enter the recommendation.

Once this recommendation is entered, NOTE then recommends a suitable NO-Till drill under the given conditions (in case No-Till is recommended). Thus, NOTE requests the user to enter the state of the soil, and the straw on the ground (Figure 12). Entering this data enables the inference engine of the ES to recommend a suitable No-Till drill under the given conditions.

A comprehensive report on what was entered during this process, and the recommendation is saved in a file. NOTE guides the user in obtaining this report (Figure 13).

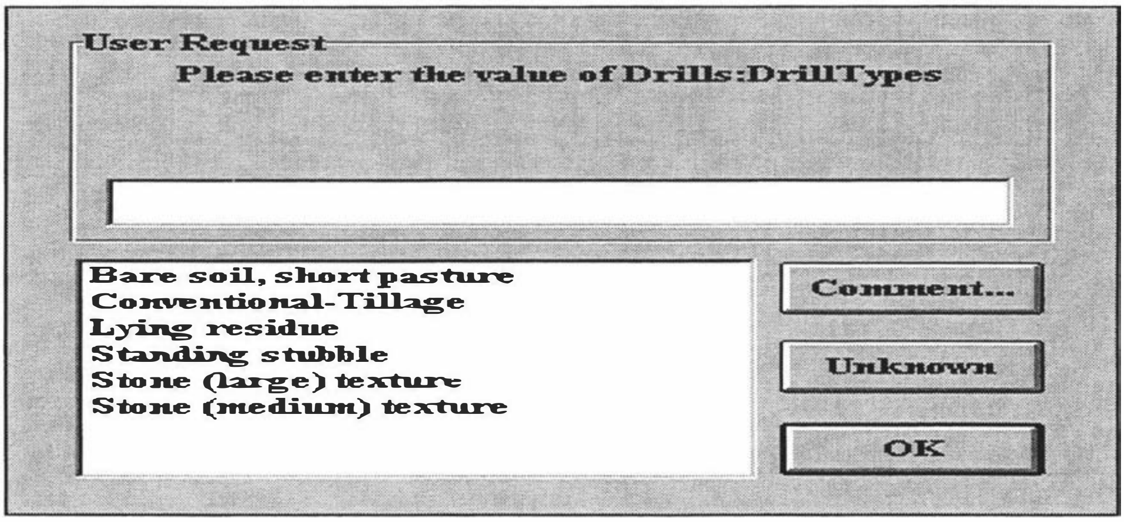

Figure 12 NOTE requesting to enter appropriate values so that a suitable No-Till drill be recommended

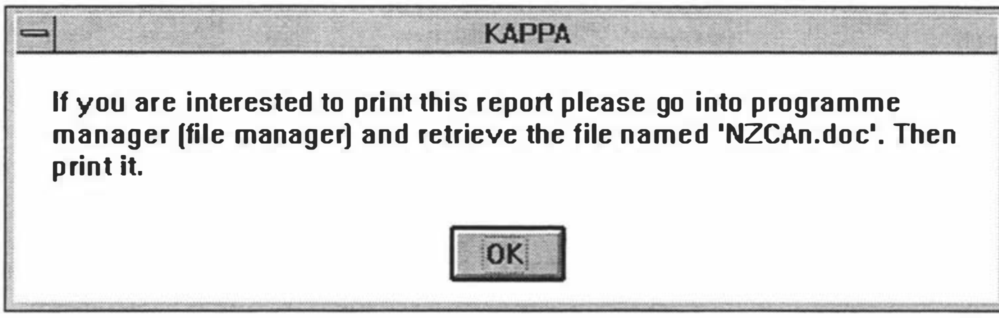

Figure 13 NOTE guiding the user about printing the report on its recommendation

A user's guide for NOTE explaining further details is attached.

Background infonnation, and the input variables considered for NOTE for Pakistani and New Zealand conditions are detailed in Chapter-6.

Chapter-6 Key input parameters for "NOTE" in Pakistan and New Zealand

6.0 Background information (Pakistan)

Pakistan lies in south west Asia with the Pamir Plateau to the north and the Arabian Sea to the south. The whole of the country lies approximately between latitude 23.5°N and 40°N and longitude 60°E and 80°E.

Pakistan's foreign exchange resources are under serious pressure because of the need to import essential agricultural commodities to meet the increasing demand for food. The Government of Pakistan is concerned with the slow progress in agricultural development, and a number of studies have been conducted to introduce new technologies (Abbas *et al*, 1996). In one such attempt, Choudhary (1983) conducted a brief survey on tillage practices and described the potential of No-Till in various soils and agro-climates in Pakistan. Choudhary *et al*, (1989) also reported a successful example of inter-disciplinary research, where agronomists, weed scientists, entomologists and engineers worked together to address various issues of No-Till planting.

The rice-wheat rotation is estimated to cover 12.6 million hectares in South Asia with tillage as one of the major costs of production (Hobbs *et al*, 1988). In Pakistan alone, cotton and rice are grown on 2.25 million and 1.8 million hectares respectively, in the summer season, making it relevant to ask whether No-Till can be used under such conditions. Based on the studies on No-Till, NOTE was applied to a case study in Pakistan.

6.1 Agriculture scenario in Pakistan

Agriculture has always been the most important sector of Pakistan's economy. At the time of independence in 1947, the agricultural sector accounted for 52% of GDP. In 1987, this sector accounted for 26% of GDP and 67% of the export earnings. The sector has maintained an annual growth rate of 4.4%. Approximately 50% of the total national labour force (66% at the time of independence) is directly engaged in agriculture, with many more engaged indirectly.

70% of Pakistan's 130 million people live in rural areas where most gain their livelihood from agricultural activities. An analysis of the contribution of individual agricultural components in GDP reveals that crops provide about 15%, while livestock, fisheries and forestry account for 10.6% of the GDP of the country. Accordingly, the contribution of crops to total agricultural GDP comes to 60.5% followed by livestock (36.8%), fisheries and forestry at 2.6% and 2.7% respectively.

6.1.1 Land and water resources

Pakistan has a total land area of 79.1 million hectares. Of this total, 19.8 million ha are classified as cropped area. The estimated area sown to crops is 15.4 million ha, and 4.4 million ha are under double cropping system. Seventy percent of the cropped area is in the Punjab. Seventy nine per cent of all cropped land is irrigated. Nearly 70% of Pakistan's agricultural area is located in the basin formed by the Indus river and four major tributaries (Jhelum, Chenab, Sutlej, and Ravi). Since rainfall is generally not sufficient for agriculture on the Indus plains, an elaborate system of irrigation has been built, primarily over the last 100 years. This system today consists of 68,000 km of canals and 225,000 tubewells. About 4 million ha of land is rainfed (Barani) agriculture production in the high plains of northern Punjab, the foothills and mountain valley of the North West Frontier Province (NWFP), some areas west of the Indus river, and in lower portions of the Sindh province. These areas can further be classified into high and low rainfall zones. Areas with rainfall above 500 mm cover 1.65 million ha and generally support dependable cropping. Areas with 300 to 500 million ha are in torrent flood and river terrain areas. These are low intensity and/or low-yielding areas that support wheat production through either runoff or residual moisture.

6.1.2 Farm size

Of the roughly 4 million farms in the country, 91% are less than 10 ha in size, 74% are less than 5 ha, and 34% are smaller than 2 ha (Table 11). Despite the number of small landholders, 36% of the cultivated area is located on farms larger than 10 ha, which comprise only 9% of the total number of Pakistan's farms.

Table 11 Number and Cultivated Area of Private Farms

(ha)	Number of farms (million)	% of Total	Cultivated Area (million)	% of Total	Av. farm size, ha
Under 2	1.4	34	1.2	8	0.9
2 to 4.99	1.6	40	4.8	30	3.0
5 to 9.99	0.7	17	4.1	26	5.9
10 to 19.99	0.3	6	2.8	18	9.3
20 to 59.99	0.1	3	2.0	13	28.0
Over 60	0.01	-	0.9	6	90.0
Total	**4.1**	**100**	**15.8**	**101**	**3.9**

6.1.3 Research for cost-effective agriculture

The Government of Pakistan is concerned with the comparatively slow progress in agricultural development during the last decade. Various studies were conducted including that in which the trend in the use of fertilizer over the last two decades was examined (Anon., 1992). The data revealed a progressive increase in fertilizer use over the base period of 1970-75 (Table 12). The table shows that the fertilizer use was only 20 kg/ha per annum during the early seventies, but increased to 92 kg/ha in 1991/92. Thus, an increase of 360% in use of fertilizer was achieved. The major causes of slow progress in agriculture during the last decade included soil salinity, greater intensity of weeds and attack of pests and diseases. However, so far no clear-cut cause has been identified for this slow progress during the period 1981 to 1991.

Table 12 Fertilizer consumption (5 years average) in relation to cultivated area in Pakistan from 1970-75 to 1991/92.

Year	Fertilizer Consumption (kg/ha)	% Change	Cultivated Area (million ha)	Area % Change
1970-75	20	-	19.3	-
1976-80	38	+90	20.0	+4
1981-85	57	+185	20.4	+6
1986-90	83	+315	20.9	+8
1991/92	92	+360	21.1	+9

Source: Pakistan Economic Survey 1991/92

Table 13 shows the annual growth rates (%) of the few major crops in Pakistan. It indicates that performance of the main crops in terms of total production as well as yield has not been satisfactory except for cotton (10.9% increase in production) and non-traditional oilseeds (7.1% increase in production). Not only have the growth rates of yields been disappointing, but also the yields themselves are very low compared to the potential yields. Surveys have clearly shown that the yields obtained by progressive farmers of the country are two to three times more than the yields obtained by traditional farmers (Table 13). Such gaps indicate the possible potential and raise hopes that crop yields can rise substantially.

The government is well aware of this precarious situation and is allocating all possible resources to enhance agricultural production, curtail imports and achieve self reliance. However, it is severely constrained by the lack of water resources for bringing culturable wasteland under cultivation. It is also evident that, generally, farmers having low land holding capacity are in situations where less costly agricultural techniques needed to be introduced. Introduction of No-Till in the early 1980s (Choudhary, 1983) may have been a step in the right direction. In 1989, while making general recommendations for improvements in crop production, Choudhary (1983) again emphasised the need for co-ordinated research into seedbed preparation, fertilizer placement and seeding methods for popularization of No-Till.

Table 13 Annual growth rates (%) of major crops in Pakistan, 1981/82 to 1991/92.

Crop	Area	Production	Yield
Wheat	+0.9	+2.9	+2.0
Rice	+0.5	-0.6	-1.1
Maize	+1.1	+2.4	+1.2
Gram	+1.3	negligible	+1.2
Sugarcane	-0.6	+0.6	+1.1
Seed Cotton	+2.6	+10.9	+8.0
Non-traditional Oilseeds	+1.3	+7.1	+5.7

Table 14 Gap between national average and potential yields of major crops in Pakistan.

Crop	Average Yield (kg/ha)	Potential Yield (kg/ha)	Un-achieved Potential
Wheat	2,029	5,533	63.3
Paddy (Basmati)	2,305	4,150	44.4
Paddy (IRRI)	3,228	6,455	50.0
Maize	1,383	5,533	75.0
Sugarcane	41,498	59,942	76.9
Cotton	553	1,199	53.9
Chickpea	553	2,951	91.3

6.1.4 Seed and seed-drill industry

Good seed is fundamental to the sustainable and profitable production of crops (Triplett, 1986). At the time of independence in 1947, Pakistan did not have the infrastructure to produce, process and supply seed to farmers. It was in the early 1960s when the Food and Agricultural Commission recognised this need and recommended the importation of high yielding Mexican wheat varieties. Pakistan has now at least two public sector seed corporations, and a few multinational private companies (such as Cargill, and Lever Brothers) to provide quality seed to farmers.

Choudhary (1983) in a study of the potential of No-Till, concluded that conditions existed in Pakistan which favoured the use of some form of direct drilling particularly in the low (up to 250 mm annually) rainfed areas. However, further research was recommended to evaluate and develop equipment and management techniques for the local conditions. Besides looking into the possible availability of various chemicals which are required under reduced tillage systems, development of an appropriate No-Till drill was also a major task. Tractors in Pakistan ranged in power from 30 to 45 kW, but most overseas No-Till drills required bigger tractors. Based on this study, the Farm Machinery Institute (FMI), under Pakistan Agricultural Research Council (PARC), Islamabad, initiated some work for developing and modifying a No-Till drill which was initially imported from New Zealand in 1984. A local agricultural machinery manufacturer was contacted, and progressive modifications were carried out on this machine to enable it to work in local conditions. In its 1991 annual report FMI described that the weight of the imported seed drill (including seed and fertilizer) was about 900 kg (540 excluding seed and fertilizer), and a 35 kW tractor's hydraulic lifting capacity was 900 to 1100 kg. Therefore, the size and consequently the total weight of the machine was reduced and its trash handling capability was improved. With these improvements in No-Till drill, and continuous six years of experiments during 1990 to 1996, FMI is currently considering the commercialisation of these drills. FMI hopes that once these drill are made available to farmers at some "reasonable" price, and other related inputs are provided, No-Till of wheat (particularly after rice) will become popular in Pakistan.

6.2 Introduction of No-Till in Pakistan

The Rice-Wheat and the Cotton-Wheat crop rotations are widely adopted over almost 3.0 million ha of Pakistan (Hobbs, 1985). Seeding of wheat is delayed by both cotton and rice harvest. The exact timing of seeding wheat in the cotton-wheat areas is influenced by the cotton variety (maturity), and the farmer decision as to whether to have an extra cotton picking. In rice, variety is also an important factor in the delay of wheat planting which results in a decrease in wheat yield (Hobbs, 1985).

In cotton-wheat area, seedbed preparation is relatively easy following removal of cotton sticks; the soil is relatively friable and can be prepared for wheat quickly. In the rice areas, the situation is different. About one-half of the rice in Pakistan is grown on puddled clay and clay-loam soils. Therefore, the farmer is faced with a hard, structureless mass of soil for sowing wheat. This takes time and, where soils are heavy in texture, final seedbed preparation may be poor. Pre-irrigation or rainfall at the time of land preparation further delays planting of wheat by 2-3 weeks. Hobbs 1985; and Hobbs *et al,* (1988) reported that delaying the planting of wheat after mid-November causes losses in grain yield at the rate of 1% per day.

In order to overcome this delay in planting No-Till planting of wheat is encouraged which saves the conventional seedbed preparation of the soil. In a CIMMYT report, Aslam *et al*, (1989), also recommended that No-Till was a potential solution to the problems of poor land preparation, poor stand, and land planting. As elaborated elsewhere, despite its limitations, the No-Till method of planting wheat has given significantly higher yield compared to conventional method of wheat sowing in Pakistan. Therefore efforts are underway to introduce this technology in Pakistan on a wider scale (Pers. Comm. Mr Gill*, 1997).

* Director General, Agriculture, Govt. of Punjab, Pakistan

6.2.1 Methodology for technology change

The International Service for National Agricultural Research (ISNAR) study on organization and management of on-farm client-oriented research indicated that effective links with extension or other technology transfer agencies were essential for broad impact (Ortiz *et al*, 1991). Forging such links had been a weak point in many on-farm research efforts in developing countries. Sometimes, it was assumed that on-farm research efforts could substitute for technology transfer efforts. For example, a study on Guatemala by ISNAR concluded that on-farm research could provide a focal point for developing strong links, but such direct links with farmers alone were not sufficient for wide dissemination of technologies (Ortiz *et al*, 1991). Based on this study and numerous meetings with the extension staff at Pakistan Agricultural Research Council, Islamabad, Pakistan, the following model (Figure 14) of technology change was established for introducing No-Till in Pakistan.

6.2.2 Mechanics of the Model

In each pilot area where No-Till is planned to be introduced, a reasonable sample (forty) of farmers should be selected for an ***informal survey*** to ascertain public reaction to No-Till. NOTE should be used while selecting these farmers. Once these farmers think that the ***general census*** is in favour of No-Till, then they would be considered the Impact Area Farmers (IAF), serving as the nucleus sites for obtaining relevant information during the introductory process. These farmers would also then serve as travelling point to disseminate No-Till technology into adjoining areas. A ***rapid rural appraisal*** by a multi-disciplinary team comprising crops, natural resources, and the social scientists will also be conducted within IAF. At this stage the ***participation of public and private sectors*** will also be sought. Based on the success of No-Till, and knowing that NOTE recommendations are correct and consistent, a full-fledged program ***of transfer of No-Till technology and***

supply inputs would be initiated. Of course, like all other models, the ***monitoring and evaluation*** will be an important component of the model.

It is anticipated that the following model will give useful feedback for modifying NOTE during the process of implementation.

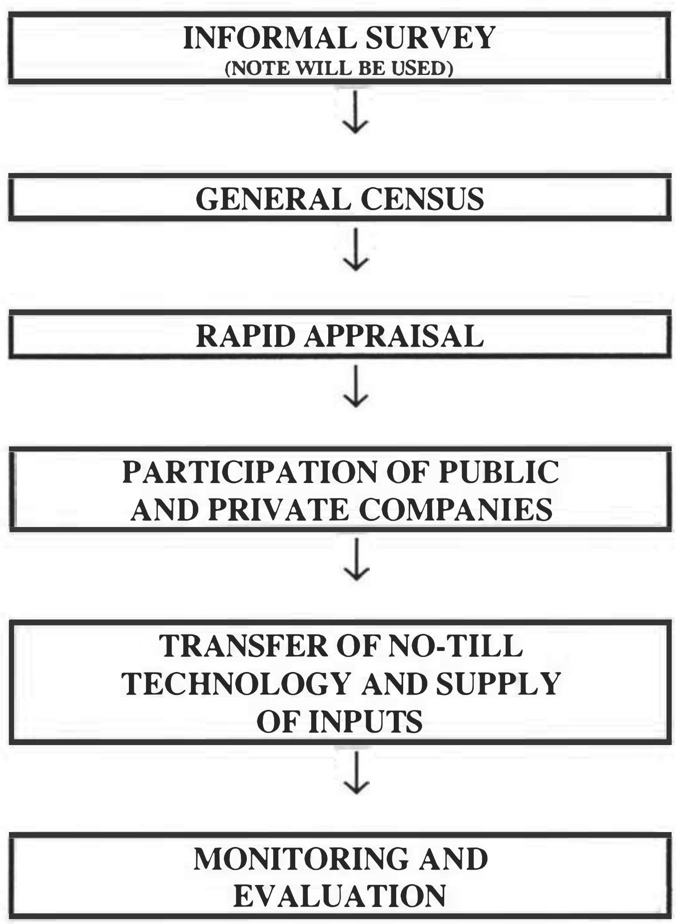

Figure 14 Model for introducing No-Till in Pakistan

6.3 Constraints to adoption of No-Till (Pakistan)

6.3.1 Social

No single tillage system can be used for all soils and agro-ecological environment. Lal (1979) observed that tillage systems were locale specific, and should be developed for all conditions to solve specific problems of soil and water management, cropping systems and energy needs of the region. In 1993, the FAO* identified the following priorities for the development of No-Till:

(i) to develop cheap alternative methods of weed control.

(ii) to develop effective and specific herbicides without harming the subsequent crop.

(iii) to develop suitable crop rotations including cover crops, and improved cropping sequences that may result in more effective storage of rainfall and efficient utilization of available soil water.

(iv) provision of appropriate equipment for planting and fertilizer application.

The major constraints to the adoption of No-Till in Pakistan include the socio-economic sphere of the farmers that usually makes them reluctant to change from present practices, and the shortage of suitable equipment (special No-Till drill). Scarcity of foreign currency which discourages the import of new machinery or purchase of spare-parts for No-Till drills and the lack of funds for research and development are associated constraints to the dissemination of No-Till technology in Pakistan.

* Anonymous (1993)

6.3.2 Technical

Stem borer is a destructive pest of rice in Pakistan which hibernates in the rice stubble. The farmers are required by law (Insect Pest Control Act 1959) to uproot and destroy the stubble by the end of February and to delay the planting of rice nurseries until 20th May in order to destroy the larvae surviving in the stubble. This Law is loosely followed by the farmers (Inayatullah *et al,* 1989). Many fields are left with rice stubble after the February limit, including fields sown to berseem (which is planted directly in standing rice stubble), low lying fields left fallow because these can not be ploughed and poorly prepared wheat fields with wheat stubble remain on the surface. Thus, an integrated approach combining the local cultural and chemical methods for stem borer control may help in introducing No-Till in rice-wheat rotations. A model (Figure 15) (Choudhary *et al,* 1989) attempts to describe the necessary decisions and actions required to reduce the risk of stem borer on rice, if farmers use No-Till.

6.4 Soil condition

As described elsewhere, there is no single tillage method that can be universally applicable to all soils, crops, climate, cropping systems and socio-economic conditions (Lal, 1990). Wilkinson (1975) described the following soil conditions which favoured No-Till:

a) there should be an adequate depth of friable, well-developed soil aggregates;

b) the surface soil should be sufficiently mechanically weak to allow the drill to work satisfactorily, and for the free movement of water and gases; and

c) there should not be enough crop debris on the surface to complicate drilling or to harbour pests.

Like in other parts of the world, the potential advantages of No-Till also apply to Pakistani conditions, though their weighting may vary from place to place depending upon the general topography and climatic factors. The major soil factors which are important in relation to the use of No-Till in Pakistan are (Choudhary, 1983):

- Well-drained light to medium soils tend to favour the use of No-Till.
- Less drained heavier soils under wetter conditions are also suitable for No-Till.
- Undrained clayey soils are not suitable for No-Till.

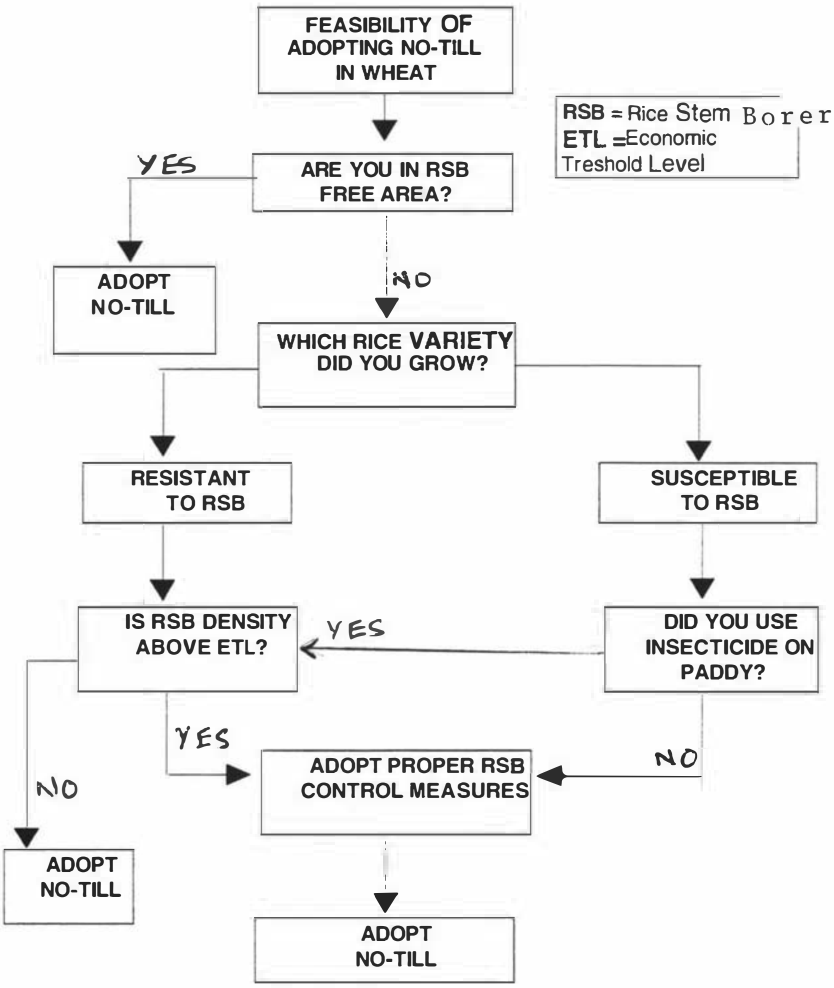

Figure 15 No-Tillage adoption model (Choudhary *et al,* 1989), p. 53

Choudhary (1983) also broadly categorised (Figure 16) the agricultural areas of Pakistan for their potential use for crop production by No-Till. According to this Figure, the major rainfed areas of D.I.Khan and D.G.Khan divisions and the surrounding districts appear to have the highest potential for No-Till. Similarly, an area towards North West of Pakistan has been classified as having potential for No-Till. These areas have high intensity annual rainfall (up to 1400 mm) which induces soil erosion, particularly in the cultivated soil.

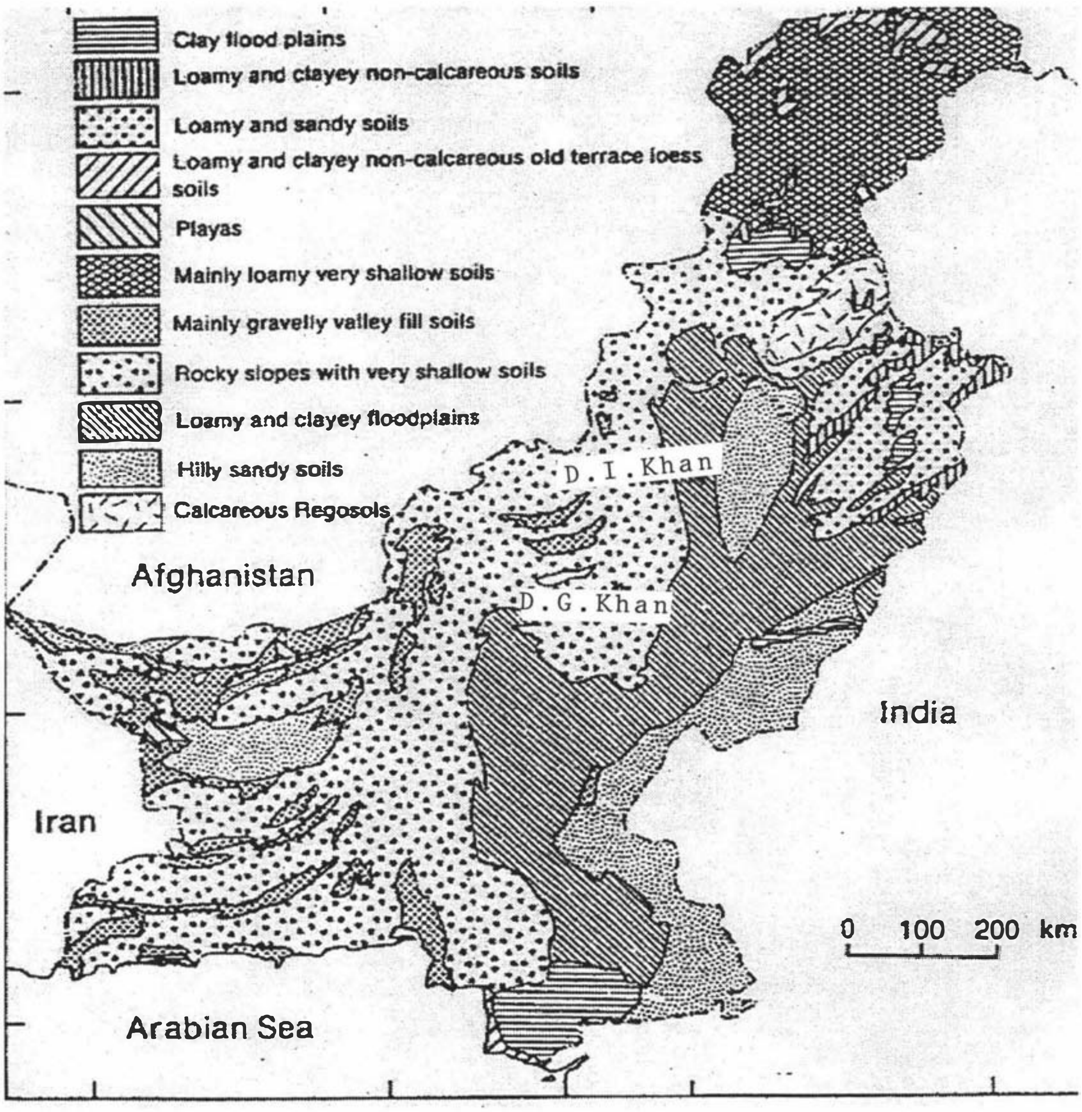

Figure 16 **Classification of Pakistani soils for No-Till**

Therefore, NOTE in Pakistani situation recommends to adopt "No-Till" (if other variables also favour) when soil type is either sandy to sandy-loam or silt loam. However, continuation with conventional tillage method is recommended for clayey soils. If "soil type" is the only criteria while asking for a choice of a tillage system, NOTE suggests to choose either conventional or No-Till (whatever the case may be), with a note that more data is required for a comprehensive and more reliable recommendation.

Based on above discussion, NOTE contains the following rules related to soil when choosing or rejecting No-Till: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: SoilClayey
*************************************/
```

If soil type is clayey

Then: PostMessage ("Undrained clayey soils are not suitable for adoption of No-Till. However, if drained, could be suitable for No-Till.")

```
/*************************************
**** RULE: SoilLoam
*************************************/
```

If soil type is sandy, sandy loam, or silt loam

Then: PostMessage ("Sandy to sandy loam and silt loam soils are suited to No-Till. Generally, all well drained soils are also suitable for No-Till cropping.")

6.5 Crop rotation

In Pakistan, the rice crop is rotated with various winter crops mainly wheat. However, to a lesser extent oilseeds, chickpeas, lentil, and clovers as fodder crops also followed after rice or cotton. Other crops such as maize, sugarcane and miscellaneous vegetables are also cultivated after these crops. According to land use statistics, cotton and wheat crops are sown on an area of 2.28 and 5.66 million hectares respectively in the cotton-wheat area in Pakistan (Anon., 1992). According to another survey report (Hobbs *et* *al*, 1988) nearly 70% of wheat following cotton is planted after 15th. December while its appropriate sowing time in the cotton area falls in the last three weeks of November. It is also reported that about 50% of the cotton fields are sown to wheat and accordingly this amounts to an area of 1.14 million hectares i.e. 20% of the total wheat area. The delay in wheat planting after cotton in this area tends to reduce wheat production. Thus, No-Till is seen as an alternative mean of sowing wheat under such conditions.

The farmers face a similar situation in the Rice-Wheat rotation. Two major rice varieties are cultivated. Basmati variety (mostly Basmati-385) covers 80% of the area while coarse variety such as IR-6 and other local varieties cover the rest of the area. Basmati-385 is a comparatively late maturing variety than IR-6 or any other coarse varieties. The average turn-around time for wheat after Basmati rice is about 18 days compared to 29 days after IR-6 and other varieties. A lot of acreage of wheat sown after rice is planted late due to long duration of Basmati rice varieties result in decrease of wheat production under this cropping pattern. To overcome the delay in planting of wheat after rice, poor land preparation; and poor establishment/stand, No-Till method of wheat planting is encouraged.

Agricultural scientists at Pakistan Agricultural Research Council, Islamabad in its one Agricultural Extension pamphlet recommended the following wheat planting technique under No-Till:

WHEAT PLANTING UNDER NO-TILL

Recommended Agronomic Practices

1.	Time of planting:	2nd fortnight of November
2.	Irrigation for broadcasting seed	4 inches
3.	Seed soaking	8-12 hours
4.	Seed rate	60 kg/acre
5.	Fertiliser	150-115-60 NPK kg/ha (All P and K with $1/3_{rd}$.N with second irrigation, and the remaining ($2/3_{rd}$.) N in Mid. January.

Research in Pakistan (Aslam *et al*, 1989) have shown (Table 15) that wheat yields using an inverted-T coulter seed drill imported from New Zealand were equivalent to wheat yields with tillage when the plots were planted on the same day. They further showed that No-Till plots had a yield advantage over tilled plots when the No-Tilled plots were planted soon after rice harvest and before the tilled plots (Table 16). Aslam *et al*, (1989) also observed that weeds were less problematic in No-Till plots than in the tilled plots, probably because of the very distinct differences in weed species that grow in the rice and wheat seasons.

Table 15 A comparison of wheat yields using an inverted-T coulter seed drill and conventionally tilled wheat planted on the same day.

	Grain yield (kg/ha)
- No-Till	3,520
- Conventional	3,410

Table 16 A comparison of No-Till versus conventional planting of wheat when planting at different dates in Punjab, Pakistan

Location	**No-Till (kg/ha)**	**Conventional (kg/ha)**	**Difference in Planting days**
Mundair Sharif	4,250	2,660	33
Mauglamania	2,691	2,200	22
Daska	3,145	3,245	16
Ahmednagar	4,312	3,529	12
Glotian	3,845	2,737	12
Average	**3,649**	**2,874**	**19**

Based on above discussion, the rules related to crop rotations in NOTE read as follows: (for details please see Appendix-Rules)

```
/************************************
**** RULE: VarietyEarly
************************************/
```

If the harvested crop was rice or cotton

Then: PostMessage ("Depending upon the harvested rice variety, wheat can be sown after rice (or cotton) with No-Till. Thus, depending on the other variables, both No-Till or conventional methods can be considered.")

```
/************************************
**** RULE: VarietyEarly
************************************/
```

If the harvested rice variety was an "early maturing" or "mid maturing" variety

Then: PostMessage ("To overcome the delay in planting of wheat after Rice and Cotton, No-Till is encouraged. Thus, depending on other variables, both No-Till or conventional methods can be considered.")

```
/************************************
**** RULE: VarietyLate
************************************/
```

If the harvested rice variety was a "late maturing" variety

Then: PostMessage ("To overcome the delay in planting of wheat after harvesting late maturing rice (or cotton) varieties, No-Till is encouraged")

6.6 Weed and pest problems

Herbicides and pesticides are both generally expensive and have to be used selectively in conjunction with proper rotations and with efficient use of crop residues for controlling weeds and pests. Weeds are also a major yield limiting factor in the rice-wheat cropping system of the subcontinents (Hobbs *et al*, 1988). In Pakistan, for example, the winter grassy weeds germinate when temperatures drop to critical levels and this becomes a major constraint to higher wheat production (loc. cit.). However, there is plenty of data available concerning suitable herbicides for controlling the weed in this cropping rotation.

Rice stem borer (*Scirpophaga incetulas*) is also a potential constraint to the adoption of No-Till for wheat. Choudhary *et al*, (1989) described a model (Figure 14) leading towards adopting or rejecting No-Till in a farm located in the stem borer area. The model recommends wheat planting under No-Till in a stem borer free area. However, within stem borer area too, wheat can still be planted under No-Till, after proper stem borer control measures are undertaken.

Aslam *et al*, (1991) studied the effect of No-Till on seed emergence rate and weed population. They reported 19% better seed emergence under No-Till than conventional methods. They argued that in the conventionally tilled soil seed is buried too deep and its emergence gets difficult. Therefore, in No-Till, seed emergence percentage is better than conventionally tilled crop. Moreover, it was further reported, that due to more disturbance of soil in the case of conventionally tillage, weed seeds get onto the surface and germinate. Therefore, 43% fewer weeds were counted under No-Till wheat planting in the rice-wheat area in Pakistan.

Choudhary (1983) reported that "herbicides desiccate the existing grasses for few weeks removing the competition and giving enough time for sown seeds to germinate and establish into plants." Most of the newly introduced chemicals leave no, or little, toxic residues in the soil as they seem to break down when in contact with the soil. Therefore, if properly applied, the fear of contamination does not arise.

NOTE therefore recommends rejection of No-Till in the RSB affected areas. However, NOTE recommends to adopt No-Till in RSB affected, only if requisite pesticides were available to deal with the RSB problem, and the recommendation is reversed if the pesticides were not available.

Based on above the discussion, the rules related to weed and pest management in the decision making process of NOTE read as follows: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: RSBNo
*************************************/
```

If the area is not affected by Rice Stem Borer (RSB) attack

Then: PostMessage ("If farm is not RSB affected then No-Till can be adopted. If it is within RSB affected zone but requisite pesticides are available, even then No-Till can be considered.")

/************************************
**** RULE: RSBYes
************************************/

If the area is affected by RSB attack

Then: PostMessage ("In case farm is affected by RSB and requisite pesticides are not available, conventional tillage suits. However, if pesticides are available, No-Till can also be considered.")

/************************************
**** RULE: ChemicalsAvail
************************************/

If requisite chemicals are available

Then: PostMessage ("Chemicals play an important role in crops sown under No-Till methods. Availability of requisite herbicide chemicals is essential for adopting No-Till.")

/************************************
**** RULE: ChemicalsNotAvail
************************************/

If the herbicides chemicals are not available

Then: PostMessage ("Chemicals play an important role in crops sown under No-Till methods. If requisite herbicide chemicals are not available conventional tillage suits.")

6.7 Straw residue management

In hot and humid situations, such as in Pakistan, cultivation results in the loss of moisture and needs irrigation to provide sufficient moisture for germination. In No-Till, the straw residue keeps the moisture reserved, which can save up to one irrigation (Griffith and Wollenhaupt, 1994). However, problem arises when wheat is drilled directly into the rice stubble. As explained in section 6.1.6 the spring tines attached with No-Till drill need to be of high standard so that they can penetrate into the straw residue, and drop the seed at an appropriate depth. With the efforts of local research in Pakistan, such a drill is now available and it is anticipated that if the price of No-Till drill remained within the buying or hiring power of the farmer, No-Till in the rice-wheat, and the cotton-wheat areas of Pakistan would flourish.

NOTE has asked its user if the "straw residue" from the previous crop was removed or left on the surface. In the case where the straw was left on the surface, NOTE recommends to adopt No-Till, otherwise NOTE recommends to continue with conventional tillage technique. However, the management of the "straw residue" is not the sole criteria for recommending a suitable tillage technique in NOTE. It combines with other factors, such as availability of a suitable No-Till drill capable of penetrating into the straw. Thus, when straw is left on the ground, and the requisite No-Till drill is also available, NOTE will recommend No-Till in such conditions.

Based on the above discussion, the rules related to straw residue management in the decision making process of NOTE read as follows: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: StrawRemoved
*************************************/
```

If the straw residue of the previous crop was removed

Then: PostMessage ("If straw residue from previous crop was removed, direct-drill is available, and seed micro-environment is also moist or wetter, No-Till suits.")

/*************************************

**** RULE: StrawLeft

*************************************/

If the straw residue of the previous crop was left on the surface

Then: PostMessage ("If straw residue from previous crop was left on the surface, and No-Till Drill is also available which can penetrate into this straw for seed placement, then No-Till suits.")

6.8 Seeding technology

Availability of No-Till drill has been considered the most important factor in adopting or rejecting No-Till. Choudhary and Baker (1981) confirmed that differences in emergence do exist between different coulter designs, with their success determined by their ability to retain and utilise the liquid and vapour moisture present in the micro-environment. Tessier *et al*, (1991) also demonstrated that seeding tool design can influence emergence and that this can be used to develop precise guidelines for future designs of furrow openers and press wheels. Thus, good seed emergence can usually be achieved by sowing in the wetter soils and by using press wheels to get a good soil-seed contact (Tessier *et al*, 1991).

In NOTE, however, owning or not owning a No-Till drill has not been considered as one (or the only) major component for adopting or rejecting No-Till. In NOTE, the user is asked about the "availability" of No-Till drill, rather than "exclusively owning" it. In the case of an "access" to a No-Till drill, NOTE recommends No-Till. In cases, where such No-Till drill is not available No-Till is not recommended.

Once the recommendation on accepting or rejecting No-Till is made, NOTE is then capable of recommending a suitable NO-Till drill under the given conditions. Thus, NOTE requests the user to enter one of the following soil and straw residue conditions:

1. Bare soil
2. Stone (large) texture
3. Stone (medium) texture
4. Lying residue
5. Standing stubble

Entering any of the above value enables NOTE to recommend a suitable No-Till drill (see section 5.1.6.1).

No-Till drills require more power to pull than their tillage counterparts (Baker *et al*, 1996). It is a general observation that farmers having tractors from 30 to 50 kW range generally have low land holdings, thus they need to adopt No-Till. On the other hand, farmers with bigger tractors may also have a wide range of agricultural equipment. Thus, depending upon other factors, No-Till or conventional method, either can be adopted.

Based on above discussion, the rules related to availability of No-Till drill in NOTE read as follows: (for details please see Appendix-Rules)

```
/************************************
**** RULE: DrillAvail
************************************/
```

If a No-Till drill is available

Then: PostMessage ("If farmer has access to a No-Till drill which can work in local conditions, and can penetrate into straw residue (if left), then No-Till suits.")

/************************************

**** RULE: DrillNotAvail

************************************/

If a No-Till drill is not available

Then: PostMessage ("If farmer has not any access to a No-Till drill, conventional tillage method should continue.")

/************************************

**** RULE: StoneMed

************************************/

If the soil has medium stones in its texture

Then: PostMessage (Light drills with spring tine legs and limited depth control winged or hoe openers are suitable under such conditions.")

/************************************

**** RULE: StoneLar

************************************/

If the soil has large stones in its texture

Then: PostMessage ("Heavy duty No-Till drills with parallel floating drag arms having winged openers are suitable under such conditions."));

/************************************

**** RULE: StandStubble

************************************/

If the soil has standing stubble

Then: PostMessage ("Light or heavy duty No-Till drills with parallel floating drag arms having winged or hoe openers are suitable under such conditions.")

/************************************

**** RULE: LyingResidue

************************************/

If the soil has some lying residue

Then: PostMessage ("Conventional drills with floating arms or any heavy duty No-Till drill with floating drag arms are suitable under such conditions.")

/************************************

**** RULE: BareSoil

************************************/

If the soil was bare, or has a short pasture

Then: PostMessage ("Light or heavy duty drills with spring tine legs, floating drag arms, and limited depth control having winged or hoe openers are suitable under such conditions.")

/************************************

**** RULE: TractorSmall

************************************/

If the available tractor power range is 45 to 70 HP

Then: PostMessage ("Farmers having tractors 45-70 HP range are generally have low land holding capacity. These are the farmers who need to adopt No-Till.')

/************************************

**** RULE: TractorLarge

************************************/

If the available tractor power is more than 70 HP

Then: PostMessage ("Farmers with bigger tractors may also have other range of agricultural equipment. Depending upon other factors, No-Till, or conventional method, either can be adopted.")

6.9 Soil moisture

Like in much of the rice-wheat cropped land of south and south-east Asia, in Pakistan too, only limited irrigation water is available (Hobbs *et al*, 1988). The issue of using this water becomes more important when, for example, only one irrigation is available. In the rice-wheat systems in Pakistan, the timing of first irrigation is critical as waterlogging frequently occurs after an irrigation as there is normally the problem of restricted rooting zone caused by the hard soil underneath and slow percolation of water. Hobbs *et al*, (1988) showed that since young wheat seedlings are sensitive to waterlogging, early irrigation often results in yellowing of plants and reduction in plant stands. Pre-irrigation before seeding has been suggested as a means to avoid waterlogging during the establishment phase (Saunders, 1985), when research showed that pre-irrigation before broadcast seeding and mulching on No-Tilled soil improved plant establishment by 42%.

NOTE has considered that if the soil was "dry" around seed placement area, then conventional tillage may be practised so that the "moist" soil can be brought near the surface and help in germinating the seed. However, NOTE recommends the adoption of No-Till in the "moist" or "wetter" soils.

Based on above the discussion, the rules related to soil moisture in NOTE read as follows: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: MoistureDry
*************************************/
```

If the soil around seed micro-environment is dry

Then: PostMessage ("If the soil around seed micro-environment is dry, and no suitable No-Till drill is available for seeding, then conventional tillage suits.")

```
/*************************************
**** RULE: MoistureMoist
*************************************/
```

If the soil around seed micro-environment is moist

Then: PostMessage ("If the soil around seed micro-environment is moist, and a suitable No-Till drill is also available for seeding, then No-Till suits.")

6.10 Key input parameters for "NOTE" in New Zealand

6.11 Agriculture scenario in New Zealand

Stretching about 1800 km, New Zealand is located between latitudes 34°S and 47°S and the country is divided into two more or less equally sized main islands. Mean daily maximum temperatures in summer range from 25°C in Northland to 19°C in Southland. In winter, this range is 14°C to 8°C respectively. No part of the land is more than 150 km from coast, the nearest neighbour, Australia, being 2000 km away.

The New Zealand weather pattern is dominated by oceanographic events. The temperate climate of New Zealand permits year-round plant growth, and double cropping is practised in many areas. More than 50% of New Zealand's export earnings come from a low-cost agricultural system based entirely on grass. New Zealand has 26.8 million hectares of which 9.5 million is in sown pasture or under cultivation and 4.3 million is in tussock or unimproved native grasses. The average rainfall ranges from 650 to 1500 mm, which ensures that most land remains under permanent pasture for intensive animal grazing year-round. The land is ideally suited for dairy farming and for raising sheep and beef cattle because grass grows nearly year around and winter housing for livestock is unnecessary in most cases. The livestock population of New Zealand includes 4 million dairy cows, 5 million beef cattle, 50 million sheep, 1.2 million deer, 300,000 goats, 400,000 pigs, and 50,000 thoroughbred horses. New Zealand ranks second only to Australia in wool production.

Pastures are predominantly white clover (*Trifolium repens*) and perennial ryegrass (*Lolium perenne*), and in New Zealand's west maritime climate, with generally mild winters and reliable rainfall, pastures grow throughout the year. In the central North Island, for example, daily pasture growth rates may be 15kgs of dry matter/hectare/day in mid-winter, rising to 80-100 kg/DM/ha/d in spring, giving an annual production of 15,000-20,000 kg/DM/ha on dairy farms, and perhaps 11,000 kg/DM/ha on less fertile sheep and beef farms. On one hectare, competent farmers carry 3.7 dairy cows, producing up to 700 kgs of milkfat/ha/year, or 16 breeding ewes, or 2.5 beef breeding cows, entirely on pasture. To achieve these levels of production, the animals' feed requirements must be carefully matched to pasture production and quality. Luckily, animals' peak requirements coincide with maximum pasture growth, and this grass based seasonal production enables New Zealand farmers to produce milk, beef, lamb, venison, wool, and goat fibre, at about 40% of the costs of traditional European or American agriculture.

Surface re-seeding of pasture on steep land by aerial methods and re-sowing of pasture into crop rotations on flatter land using cultivation have become common practice in New Zealand (Choudhary and Baker, 1994). The use of conservation tillage, especially over-drilling, has increased, and it is estimated that currently 250,000 ha of pasture-lands are re-sown with this method every year (loc. cit.).

In the last decades, important changes in the pattern of crop production have occurred in several countries including New Zealand. The Resource Management Act, 1991, which replaces all previous soil conservation legislation requires that New Zealand soils are managed according to the principles of sustainability (Anon., 1991). The Act empowers local authorities to control the effects of land use as necessary to promote sustainable management, including the harmful effects of soil erosion. Appropriate tools (soil quality measurements) and technologies (interpretative criteria, remedial management strategies, biological models) are being developed to enable pastoral land users (farmers, advisors, consultants) and resource managers and planners, to objectively measure, monitor and predict the long-term effects of current management practices on soil and water quality and thereby ensure sustainable land management. New Zealand farms, through the use of modern methods and machinery, have among the highest productivity levels in the world. The land is ideally suited for dairy farming and for raising sheep and beef cattle because grass grows nearly all year around. When growth conditions are favourable over a sequence of years farmers tend to simplify pasture management and reduce the area of special purpose pastures and forage crops. When adverse conditions such as drought and pest attack dictate a need for increased seasonal feed production, pasture renovation by direct drilling (No-Till) technique offers a quick, practicable method to overcome the problem. It also provides a quick procedure to maintain high quality cultivars in the sward and thereby improve the productivity of run-out pastures. This section explains how NOTE is intended to improve the adoption of No-Till by farmers by using a computerised decision support systems. Various parameters considered while designing NOTE for New Zealand conditions are described.

6.12 Pastoral based farming

Cultivation is practised on New Zealand pastoral sheep farms to remove deteriorated pastures, to allow more productive species to be introduced and prepare a seed-bed for forage crops needed to overcome feed deficits caused by cold winter conditions or summer droughts (Frengley, 1983). A productive pasture allows greater flexibility when setting calving and lambing dates and ensures the highest levels of pasture utilisation possible. On highly stocked dairy farms too, the pasture growth is maintained throughout the milking season particularly in early spring (Thom and Ritchie, 1993). These criteria also apply to deer and goat as well as dairy, sheep and cattle pastures.

Generally, when growth conditions are favourable over a sequence of years, farmers tend to simplify pasture management and reduce the area of special purpose pastures and forage crops. When adverse conditions such as drought and pest attack dictate a need for increased seasonal feed production, pasture renovation by direct drilling techniques offers a quick, practicable method to help overcome the problem (Pottinger *et al*, 1993). No-Till has offered practical means of improving pastures in New Zealand. Surface re-seeding of poor pastures on steep land by aerial methods and re-sowing of pastures into crop rotations on flatter land using cultivation have also become common practice. Thom and Ritchie (1993) described following advantages of pasture renovation using herbicides:

(a) Lengthy fallow periods are not necessary. Because pastures are not out of production for long periods increased productivity per hectare is possible.

(b) Time and energy saving. The method is less labour intensive and equipment costs are lower.

(c) Less capital intensive.

(d) Improved control of troublesome weed species is possible.

(e) Cost effective.

(f) Better management of pests such as grass grub and Argentine stem weevil.

(g) Ease of implementation.

(h) Quicker utilisation of pasture after sowing.

(i) New pastures are not easily pugged.

(j) Hill country is less prone to erosion.

As New Zealand's export income is heavily dependent on pasture production, its quality and quantity are both important for local farmers. No-Till has definitely had a major influence on pasture renovation and its adoption has already raised its potential biological reliability.

6.13 Major crops and cropping patterns

Mixed crop and live stock farming is practised principally in the east coast regions of both the North and South Islands of New Zealand (Frengley, 1983). Soils used for mixed cropping vary from 30 to 50 cm of top-soil over free draining sand and gravel. The sand, silt and clay fractions of the top soil vary and cultivation times per hectare increase as the clay and silt fractions increase. Typical mixed crop and livestock farms grow a variety of crops; cereals, crucifers, oil seed crops, grass seed and clover crops are the most common seed crops while brassica, lupins and ryegrass and cereals are used for winter forage. Crops are grown in rotation to maintain soil fertility and avoid disease and mixed ryegrass and white clover pasture is often sown at the end of the rotation to improve soil structure and fertility. The pasture is retained for one or more years before the land re-enters the rotation (loc. cit.).

Literature reveals (Lal *et al*, 1994; Ehlers, and Claupein, 1994; and Steed *et al*, 1994) that conservation tillage offer distinct advantages to mixed cropping and livestock farmers and the practice had become increasingly favoured lately.

6.14 Seed Drilling Technology

Excessive cultivation has been regarded as one of the major cause of soil degradation in New Zealand. However, a distinct shift in pasture establishment practises from traditional conventional cultivation to direct drilling has occurred in New Zealand and Australia over the years (Ritchie, 1986b; Thom *et al*, 1987b; Barker *et al,* 1989; Bellotti and Blair, 1989a). On the other hand, reduced tillage practices carried the possible fears that residue covered soils may adversely affect seed germination and reduce root development from direct residue contact (Goss *et al,* 1984; Lynch, 1978). Choudhary and Baker (1988) found that such scenarios could be avoided by separating residue and the sown seed using a separation mechanism in seed drill openers. Thus, the quantity and distribution patterns of plant residue on the soil surface have a major influence on the design of soil-engaging tools for proper residue management. A number of types of drill openers have been tried for drilling cereals through stubble or residue with varying degree of success. Among those, a winged opener developed at Massey University, Palmerston North (Cross Slot™)[1] has been shown to successfully seed through a wide range of residue conditions while maintaining a complete soil and residue cover over the seed and avoiding seed-residue contact (Baker *et al*, 1979; Baker and Choudhary, 1988).

Choudhary and Baker (1994) described three distinct markets for No-Till machines in New Zealand and Australia. These were categorised based on their initial cost, annual usage, and sophistication of the operations. The categories were:

1 Low-cost pasture renovation machines.
2. Low-cost No-Till cropping drills.
3. Sophisticated No-Till drills.

It was evident from reviewing the literature (Choudhary and Baker, 1994) that no single machine can handle a wide range of soil types and residue conditions for either conventional or No-Till. In the case of No-Till, however, it is not simply economical for farmers to own several drills to cope with varying soil and residue conditions. Thus, a successful No-Till drill must have a much wider range of capabilities and sophistication than their equivalent tillage tools.

Choudhary and Baker (1994) concluded in one of their studies on this subject that with the development of drill technology, conservation tillage, especially No-Till has become an accepted technique. These technologies match current chemical technologies and may form the basis of the next generation machines. These new machines will then target and utilize the potential of untilled soils and surface crop residues. There has been numerous examples

1 Mention of trademarks or vendors do not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

where such machines have already raised the potential biological reliability of No-Till to a higher level than that achievable under conventional tillage.

6.15 Constraints to adoption of No-Till (New Zealand)

The constraints on conservation tillage in New Zealand are considered more philosophical than technical (Choudhary and Baker, 1994). While on one hand, the New Zealand farmers are among the most educated and technically literate farmers in the world; on the other hand, less population, and the buying power of only 60,000 farmers represent a compact, and often uneconomic basis for manufacturing and marketing larger and expensive agricultural machines for conventional or No-Till. The cost involved with sophisticated drills favour large annual usage of the machines, which contrasts with relatively small intensive farm units. No-Till has gained acceptance as an efficient method of crop establishment in New Zealand, and farmers who have used this technique have identified support expertise as one of the key inputs of its success (Choudhary and Baker, 1994). A survey of farmers who have used No-Till have urged that conservation tillage (No-Till) must be capable of being applied by a wide range of farmers under a wide range of farming conditions with knowledgeable support expertise. Therefore, training of skilled consultants who can apply No-Till and management is needed to help farmers during transition phase. Last but not the least, another reason for reluctance shown towards No-Till by a few farmers has been their concern regarding environmental issues; many do not want to use excessive chemicals.

6.16 Soil texture

Different crops require different seedbed conditions and not all soils can be cultivated in the same way. A systematic examination of soil profile can help to identify soil physical problems which may be affecting plant growth and can be used to help make decisions about suitability of a particular tillage technique for specific paddock or crop. McLaren and

Cameron (1996) reported that deterioration of soil structure can be reduced by minimising the amount of cultivation and by ensuring that organic matter levels are maintained. They have recommended adoption of direct drilling, minimum cultivation or any other form of conservation tillage techniques where soils are at risk. In New Zealand, the soils are generally recent and shallow, with limited water holding capacity (Choudhary and Baker 1994). Most soils which are extensively cropped are alluvial in origin, but there are few examples of self-mulching and sticky clay soils (loc. cit.). Literature reveals that attempts to classify soil suitability to conservation tillage have been controversial because data are often biased by the performance of the dominant drilling technology at the time. Within these limitations, however, Ross and Wilson (1983) classified some New Zealand soils, under which most of the arable areas of New Zealand were felt to have slight or moderate limitations to the conservation tillage techniques. NOTE has considered these values while making any recommendations for No-Till in New Zealand conditions. Therefore, if the soil type is either sandy or sandy loam, NOTE recommends to adopt No-Till, while conventional tillage is recommended for clayey soils.

Based on above discussion, NOTE contains following rules related to soil when choosing or rejecting No-Till: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: SoilClayey
*************************************/
```

If the soil type is clayey

Then: PostMessage ("Undrained clayey soils are not suitable for adoption of No-Till. However, if drained, could be suitable for No-Till.")

```
/*************************************
**** RULE: SoilLoam
*************************************/
```

If the soil type is either sandy, sandy loam or silt loam

Then: PostMessage ("Sandy to sandy loam and silt loam soils are suited to No-Till. Well drained soils coming out of pasture are also suitable for No-Till cropping.") recommendation.")

6.17 Crop rotation

Many crops in New Zealand are grown in rotation with a grass/clover pasture, - a system called 'mixed cropping'. The exact nature of the rotation also greatly depends on factors such as soil texture, climate and type of crops grown. Choudhary and Baker (1994) reported that while many temperate arable crops are grown in New Zealand, these are generally rotated regularly with permanent pastures and animal-based farming systems which serve to repair or preserve soil structure, fauna, and organic matter. The traditional approach of maintaining soil organic matter levels is to alternate periods of cropping with periods in which soil is sown down to grass or grass/clover pastures. The periods in pasture help to replace organic matter lost under cropping and restore any structural damage that may have occurred (McLaren and Cameron, 1996). As, cultivation methods of sowing pasture are expensive, and potentially harmful (Choudhary and Baker, 1994) the use of conservation tillage, especially over-drilling, has increased in recent years in New Zealand. No-Till allows the reduction of fallow periods (traditionally 4 to 6 weeks) between pasture and spring sown crops. NOTE has thus considered the possibility of using No-Till and replacing it with conventional tillage practices where-ever suitable soils (well drained) exists. NOTE also recommends to adopt No-Till when pasture has to be "over-drilled". However, it recommends to continue with conventional tillage after harvesting of a cereal crop, or when converting pasture to cereal production as it is recommended to sow an intermediate crop such as fodder to avoid pest transfer (Baker *et al,* 1996).

Based on above discussion, the rules related to crop rotations in NOTE read as follows: (for details please see Appendix-Rules)

```
/************************************
**** RULE: CerealPasture
************************************/
```

If the harvested crop is a cereal crop and the next crop is pasture

Then: PostMessage ("When converting cereals to pasture production, No-Till is not suitable.")

```
/************************************
**** RULE: CerealCereal
************************************/
```

If the harvested crop is a cereal crop and the next is also a cereal crop

Then: PostMessage ("When growing cereals or fodder in rotation, No-Till can be employed.")

```
/************************************
**** RULE: PastureCereal
************************************/
```

If the harvested crop is pasture and the crop to be grown is a cereal crop

Then: PostMessage ("When converting pasture to cereals production, it is recommended to sow an intermediate crop such as fodder to avoid pest transfer.")

```
/************************************
**** RULE: PasturePasture
************************************/
```

If the harvested crop is pasture and the next crop to be grown is also pasture

Then: PostMessage ("Pasture renewal is commonly practiced in New Zealand by over-drilling.")

6.18 Weed and pest management

Early success with minimum tillage techniques promoted the question of whether cultivation was needed at all. Two companies ICI and Monsanto developed knock-down herbicides which could be used to control weeds before sowing (Steed *et al*, 1994). While adopting No-Till, farmers expect to control any weed problem by use of appropriate herbicides. Farmer's confidence in the use of herbicides has prompted them to look for chemical solutions to other problems such as crop disease and pests.

In New Zealand, a winter forage crop is often grown ahead of the spring planting of a summer cereal crop. The choice of winter forage species and how it would be managed greatly influence the cost and effectiveness of the chemical weed and pest control required to establish the cereal crop. Both annual and perennial weeds are prominent and grow actively year-round. Thus, it has been necessary to develop special treatments for the control of species such as dock (*Rumex obtusifolius* L.), dandelion (*Taraxacum officinale* Wiggers), stroksbills (*Erodium cicutarium* L.), and yarrow (*Achillea millefolium* L.), which are effectively controlled by tillage (Baker and Choudhary, 1994). Sometimes in an area that is badly infested with perennial weeds, it is better to first control the weed problem with a one-off tillage regime before attempting to initiate reduced tillage methods of new crop establishments. Perennial grass weeds such as couch (*Agropyron repens* L. Beauv.) and Californian thistle (*Cirsium arvense* L. Scop.) are more effectively controlled by No-Till, especially where a double-spray herbicide program can be used (loc. cit.).

Killing of existing vegetation with herbicides in the spring forces invertebrate pests to feed on the sown species (Pottinger, 1979). To ensure that the host crop species do not precede susceptible crops it has always been considered necessary to either:

- apply appropriate granular insecticides in the slot with the seed or
- change crop management

For example, the Argentine stem weevil does not overwinter on brassica forage crop, so susceptible cereals can be safely planted following a winter brassica crop. Similarly, peas (*Pisum sativum* L.) are not susceptible to Argentine stem weevil or aphid and therefore can be safely grown after a winter pasture or forage cereals, e.g. oats (*Avena sativa* L.).

Therefore, NOTE has taken care of this issue and recommends adoption of No-Till for pasture renovation, but reverses its recommendation if the harvested crop was a cereal crop.

Similarly, NOTE has also considered the availability of requisite chemicals as one of the important input variable. If these are not available, NOTE recommends "conventional tillage techniques", however, if the requisite chemicals are available, NOTE recommends "No-Till".

Based on above discussion, the rules related to weed and pest management in NOTE read as follows: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: ChemicalsAvail
*************************************/
```

If the requisite chemicals are available

Then: PostMessage ("Chemicals play an important role in crops sown under No-Till methods. Availability of requisite herbicide chemicals is essential for adopting No-Till.")

```
/*************************************
**** RULE: ChemicalsNotAvail
*************************************/
```

If the requisite chemicals are not available

Then: PostMessage ("Chemicals play an important role in crops sown under No-Till methods. If requisite herbicide chemicals are not available conventional tillage suits.")

6.19 Straw residue management

Residues from the harvested crop are considered cost-effective means of reducing environmental pollution and soil erosion. In humid climates, crop residues maintained near the soil surface have positive effects on soil structural stability (Carter, 1992). The quantity and distribution patterns of plant residue on the soil surface have a major influence on the design of any direct drill machine. Production of relatively high yields of crop residues can present problems for optimum crop establishment, wherein excessive residues interfere with seeding operations. Appropriately designed drills help in proper residue management which include avoiding any such substantial blockages and creating a favourable seed micro-environment (Baker and Saxton, 1988). NOTE asks its user if the "straw residue" from the previous crop was removed or left on the surface. Where the straw is left on the surface, and the farmer has access to a No-Till drill, NOTE recommends adoption of No-Till. However, the management of the straw residue is not the only criteria, that NOTE considers before recommending a suitable tillage technique. It is combined with the availability of a suitable No-Till drill capable of penetrating into the straw. Thus, when straw residue is left on the ground, and the requisite No-Till drill is not available, NOTE recommends to continue with the conventional tillage techniques.

Based on above discussion, the rules related to straw residue in NOTE read as follows: (for details please see Appendix-Rules)

/************************************

**** RULE: StrawRemoved

************************************/

If the straw residue from the previous crop was removed

Then: PostMessage ("If straw residue from previous crop was removed, direct-drill is available, and seed micro-environment is also moist or wetter, No-Till suits.")

/************************************

**** RULE: StrawLeft

************************************/

If the straw residue of the previous crop was left on surface

Then: PostMessage ("If straw residue from previous crop was left on the surface, and No-Till is also available which can penetrate into this straw for seed placement, then No-Till suits.")

6.20 Seeding technology

In New Zealand, No-Till has been considered better than broadcasting because in No-Till, unlike in broadcasting, the seeds are placed into the soil (Pottinger *et al,* 1993). In general, No-Till is most successful if the pasture is short and a bar or chain-harrow is used to cover the seed with loose soil to help reduce the moisture loss. As, the germination and the seedlings survival is reliant on good soil moisture and rainfall, drills such as the Aitchison "Seedmatic", Duncan "Multiseeder", and Begg direct drills have been designed specifically to place the seed directly into the soil beneath existing pasture. Other drills can possibly be adopted to drill in the untilled land by fitting hardened hoe points and stronger press springs. Duncan "Multiseeder" drill uses a triple-disc opener or coulter. In its mechanism, the leading disc cuts a deep groove, through which the trailing discs run, opening a V-shaped slot which receives the seed.

The Aitchison "Seedmatic" and Begg drills have a chisel coulter with "wings" which shatter the soil beneath the pasture surface. The seed is placed in the shattered soil zone, and is better protected from drying out than with hoe or triple disc grooves. Chisel-type openers or coulters can also be supplied with leading disc in front of each coulter to help cut through heavy trash, which otherwise builds up in front of the coulters.

New Zealand has relatively small intensive farming units, thus the cost structure involved with sophisticated direct-drills favour large annual usage of such machines. Thus, owning or not owning a No-Till drill is not a major criteria for adopting or rejecting No-Till. NOTE recommends No-Till if the farmer has an access to a No-Till drill, otherwise it recommends continuation of conventional tillage techniques.

Based on above discussion, the rules related to availability of No-Till drill in the NOTE read as under: (for details please see Appendix-Rules)

/************************************

**** RULE: DrillAvail

************************************/

If a No-Till drill is available

Then: PostMessage ("If farmer has access to a No-Till drill which can work in local conditions, and can penetrate into straw residue (if left), then No-Till suits.")

/************************************

**** RULE: DrillNotAvail

************************************/

If a No-Till drill is not available

Then: PostMessage ("If farmer has not any access to a No-Till drill, conventional tillage method should continue.")

/************************************

**** RULE: StoneMed

************************************/

If the soil has medium stones in its texture

Then: PostMessage (Light drills with spring tine legs and limited depth control winged or hoe openers are suitable under such conditions.")

/************************************

**** RULE: StoneLar

************************************/

If the soil has large stone in its texture

Then: PostMessage ("Heavy duty No-Till drills with parallel floating drag arms having winged openers are suitable under such conditions."));

/************************************

**** RULE: StandStubble

************************************/

If the soil has standing stubble

Then: PostMessage ("Light or heavy duty No-Till drills with parallel floating drag arms having winged or hoe openers are suitable under such conditions.")

/************************************

**** RULE: LyingResidue

************************************/

If the soil has some lying residue

Then: PostMessage ("Conventional drills with floating arms or any heavy duty No-Till drill with floating drag arms are suitable under such conditions.")

/************************************

**** RULE: BareSoil

************************************/

If the soil was bare soil, or had a short pasture

Then: PostMessage ("Light or heavy duty drills with spring tine legs, floating drag arms, and limited depth control having winged or hoe openers are suitable under such conditions.")

/*************************************

**** RULE: TractorSmall

*************************************/

If the available tractor power range is 45 to 70 HP

Then: PostMessage ("Farmers having tractors 45-70 HP range are generally have low land holding capacity. These are the farmers who need to adopt No-Till.')

/*************************************

**** RULE: TractorLarge

*************************************/

If the available tractor power range is more than 70 HP

Then: PostMessage ("Farmers with bigger tractors may also have other range of agricultural equipment. Depending upon other factors, No-Till, or conventional method, either can be adopted.")

6.21 Soil moisture

The water content of soil is important not only because it affects plant growth, but also because it influences soil properties such as aeration and temperature. The amount of available water which can be stored in soil is a function of six main factors: texture, structure, organic matter, soil depth, profile layering, and stone contents. McLaren and Cameron (1996) reported that organic soils can store larger amount of available water while granular soils are unable to store much available water. Physical changes to the soil caused by tillage operations can be beneficial in reducing a fine tilth, however, if cultivations are excessive or conducted when the soil is wet (not at the correct moisture content) then tillage can cause damage to soil structure. According to McLaren and Cameron (1996), many New Zealand soils have naturally compact subsoils and others have developed compact layers through cultivation practices. Lal (1990) reported that friable, coarse-textured, self-mulching, and structurally active soils are likely to respond better to

No-Till or any reduced tillage techniques than soils with massive structure or which are easily compactable.

NOTE has considered that if the soil was "dry" around seed placement area, then conventional tillage may be required so that the "moist" soil can be brought near the surface to help germinating the seed. However, NOTE recommends to adopt No-Till when the soil is "moist" or "wetter" around the seed placement area.

Based on above discussion, the rules related to soil moisture in NOTE read as follows: (for details please see Appendix-Rules)

```
/*************************************
**** RULE: MoistureDry
*************************************/
```

If the soil around seed micro-environment is dry
Then: PostMessage ("If the soil around seed micro-environment is dry, and no suitable No-Till drill is available for seeding, then conventional tillage suits.")

```
/*************************************
**** RULE: MoistureMoist
*************************************/
```

If the soil around the seed micro-environment is moist
Then: PostMessage ("If the soil around seed micro-environment is moist, and a suitable No-Till drill is also available for seeding, then No-Till suits.")

6.22 Soil slope

Olofsson (1993) reported that mouldboard ploughing cannot be used in areas that are too steep, too wet, or too stony. Direct-drilling with minimum cultivation is considered an alternative tillage technique for pasture establishment under such conditions. Naylor *et al*, (1983) carried-out several studies in Scotland and Ireland, where establishing of perennial grasses has successfully been done. Choudhary and Baker (1994) confirmed that surface reseeding of poor pastures on steep land by aerial methods and re-sowing of pasture into crop rotations on flatter land using cultivation have become common practice in New Zealand. This is in conformity with explanation given in section 5.1.8 where it was elaborated that as the slope increases the choice of a tillage system becomes more limited. Therefore, NOTE recommends adoption of No-Till once it was established that the slope was greater than 5%. However, for flatter lands, with slopes of less than 5%, both No-Till and conventional tillage techniques have been recommended. However, in such circumstances, before recommending No-Till, NOTE suggests that No-Till is encouraged only if a tractor can negotiate in such fields (Pers. Comm. Choudhary, 1997).

Based on above discussion, the rules related to soil slope in NOTE read as follows: (for details please see Appendix-Rules)

/*************************************

**** RULE: SlopeLow

*************************************/

If soil slope is low (less than 5%)

Then: PostMessage ("If field is flat and slope is less than 5%, and No-Till drill is also available, then No-Till or conventional methods both can be suitable, depending on other factors.")

/*************************************

**** RULE: SlopeMedium

*************************************/

If soil slope is medium (5 to 12%)

Then: PostMessage ("If slope is high, meaning from 5 to 12%, and No-Till drill is also available, No-Till is more suitable.")

/*************************************
**** RULE: SlopeHigh
*************************************/

If soil slope is high (more than 12%)

Then: PostMessage ("If slope is high, meaning more than 12%, and No-Till drill is also available, and tractor can negotiate slopes, then No-Till is suitable.")

6.23 Technology transfer

No-Till has gained acceptance among New Zealand farmers as an efficient method of crop establishment. To achieve continued reliability of crop yields under No-Till, farmers' access to appropriate advice on this technique should be ensured. As mentioned in section 5.2.1, a traditional cultivation system is more forgiving and repairable if incorrect decisions are made while preparing a seedbed, however, with No-Till the result is usually not obvious until it is too late and is then not easily repaired or hidden.

Choudhary and Baker (1994) claimed that unfortunately, in New Zealand the success of No-Till will remain constrained until professionally skilled consultants are available in sufficient numbers to give individual advice in the field. Because of New Zealand's comparatively small economy, this may not be possible. Thus, introduction of an expert system like NOTE can be a handy tool in such locations.

NOTE considers that if the agricultural extension facilities were "excellent" or "good", farmers should adopt No-Till, however, if they were "bad", farmers should continue with the conventional tillage methods.

Based on above discussion, rules in NOTE related to the nature of availability of agricultural extension facilities in the region read as follows: (for details please see Appendix-Rules)

/*************************************
**** RULE: TTBad
*************************************/

If the extension facilities are not good

Then: PostMessage (If local agricultural extension is not well aware with information w.r.t. No-Till (for pesticide, herbicide application etc.), then conventional tillage suits.")

/*************************************
**** RULE: TTGood
*************************************/

If the extension facilities are excellent or good

Then: PostMessage ("If local agricultural extension is providing good information w.r.t. No-Till (for pesticide, herbicide application etc.), then No-Till suits.')

6.24 Summary

There has been considerable study in the field of soil tillage and cultivation during last 40-50 years, with the emphasis being on either maximising crop yields or minimising soil erosion and drainage problems in cultivated areas. However, within the last two to three decades the technique of No-Till has become possible, due to availability of suitable herbicides.

The process of introducing No-Till has been slow in developing as well as in developed agriculture. Literature cited in previous sections describes apparent advantages of shifting towards No-Till from conventional tillage techniques. The results are normally beneficial in the longer term, and should not be weighed on each seasonal crop yields, as the main advantages of shifting towards No-Till are improvement in soil structure, better fertility level of soil, and less use of agricultural machinery.

Based on various studies, and pooling data on No-Till, the need for a computer based expert system was envisaged. NOTE is one of such attempt, and it is hoped that extension workers will be able to use this knowledge in making a more suitable and desirable decision while adopting or rejecting No-Till at their farms. NOTE is also likely to aid farmers and the extension workers in disseminating the expertise of researchers on No-Till.

Chapter-7 Validation of the NOTE System

7.1 Introduction

Verification and validation of an ES is an important processes. As the ES becomes more complex, the verification issues become more critical. The inability to adequately evaluate on ES can become a limiting factor in employing the ES for the end users (Schultz and Geissman, 1995). Jentsch (1993) quoted Hormann (1992) defining verification and validation in the context of an ES: verification is the process that investigates the agreement between design and implementation of an ES; and validation compares the product requirements and performance. In more general terms, verification could be defined by the question "Did we build the ES right?". Therefore, verification should refer to the processes that determine whether the knowledge that is acquired from the experts is, in fact, used by them when performing their tasks (Andrews, 1993). On the other hand, validation could be characterised by "Did we build the right ES?" which refers to the processes that determine whether the knowledge used in the ES is consistent and complete (Andrews, 1993). Verification and validation take place (during and) after designing an ES, but before (and during) its operation (Jentsch, 1993).

Plant and Stone (1991) explained the validation process of an agricultural based ES as a process of ensuring that the syntactically correct knowledge base is also "*scientifically*" correct. The word *scientifically* is emphasized in quotes because validation of an agricultural based ES (for example in a plant growth monitoring expert system) involves testing the system against the crop in a variety of conditions. The purpose of validation in such ES is to determine whether the solution to the equations of the ES matches accurately with the observed behaviour of the crop. If it does, then the ES is scientifically correct (or valid).

Jones and Barrett (1989) recommended that an effective validation procedure is critical to the success and acceptance of an ES. They considered validation should include: (1) correctness, consistency and completeness of the inference rules; (2) ability of the control strategy to consider information in the order that corresponds to the problem solving process; (3) appropriateness of information about how conclusions are reached and why certain information is required; and (4) agreement of the ES output with the domain expert's corresponding solutions.

This chapter discusses the steps taken for validating NOTE.

7.2 Validation of NOTE

NOTE incorporates technical, economic, and the environmental aspects associated with the use of tillage techniques. Chapter-5 explains these factors in detail. As field validation of NOTE was not possible within the duration of the study, an approach used by Xin *et al,* (1997) was used to validate this package. Earlier, Edward-Jones *et al,* (1992) used a similar approach to validate a decision support system to aid weed control in sugar beet where all possible out-puts were compared with the literature and expert recommendations. For securing consistent recommendations from NOTE, the rules and the parameters used in this ES were divided in three categories. Table 17 and Table 18 show the factors placed in the first category. These were the most important variables and any change in their values affected the final recommendation on accepting or rejecting the No-Till under Pakistani and New Zealand situations. The tables facilitate the expert system designer and the validator to place the main characters of the ES before them. This process therefore helps in constructing and verifying a complete and unambiguous record during the development and validation process of the ES (Plant, 1993).

The knowledge base of NOTE contains many rules (see Appendix-Rules). The task of the inference engine is to piece together logical chains of reasoning based on these rules before verifying a recommendation. While validating NOTE, it was made certain that any change in the value mentioned in Table 17 and Table 18 changes the recommendation on accepting or rejecting No-Till. For example, if a farmer is unable to have access to a No-Till drill, NOTE will always reject adoption of No-Till, even if other factors such as soil type, or crop rotation favour such technique. Therefore, during the validation, Table 17 was used to make certain that under the Pakistani situations, No-Till is not recommended if any of the following conditions apply:

1. If the area is affected by RSB, and the requisite herbicides are not available.

2. If the soil texture is clayey (not well drained).

3. If requisite weed control chemicals are not available.

Table 17 List of factors which affect the final outcome of the recommendation of accepting or rejecting No-Till under Pakistani situations

Factors	*Values*	*Result*	*Reference(s)*
Soil texture	**1. Sandy**	**No-Till is recommended**	**1**
	2. Sandy loam	**No-Till is recommended**	**2**
	3. Clay	***No-Till is not recommended** ***(However, if drained, No-Till is recommended)**	**2**
Availability of Chemicals herbicides	**1. Available**	**No-Till is recommended**	**3**
	2. Not available	**No-Till is not recommended**	**3**
Farm located in the RSB area	**1. Yes**		**4**
	(a) Pesticides against RSB available	**(a) No-Till is recommended**	**4**
	(b) Pesticides against RSB not available	**(b) No-Till is not recommended**	**4**
	2. No	**No-Till is recommended**	**4**
Availability of No-Till Drill	**1. Available**	**No-Till is recommended**	**5**
	2. Not available	**No-Till is not recommended**	**5**

Reference(s):

1. Lal (1979); Choudhary (1983); Blevins (1984)
2. Griffith *et al,* (1973); Lal (1979); Choudhary (1983); Ross and Wilson (1983); Lal (1985)
3. Conacher and Jeanetta (1986); Unger and Skidmore (1994); Baker *et al,* (1996)

4. Choudhary *et al,* 1989; Aslam *et al,* (1991)

5. Phillips (1984); Throckmorton (1986); Baker *et al,* (1996)

Table 18 List of factors which affect the final outcome of the recommendation of accepting or rejecting No-Till under New Zealand conditions.

Factors	*Values*	*Result*	*References(s)*
Soil texture	**1. Sandy**	**No-Till is recommended**	**1**
	2. Sandy loam	**No-Till is recommended**	**1**
	3. Clay	***No-Till is not recommended** ***(Well drained soils coming out of pasture are suitable for No-Till cropping)**	**2**
Crop rotation	**1. Cereal-Pasture**	**No-Till is not recommended**	**3**
	2. Over-drilling pasture	**No-Till is recommended**	**4**
	3. Cereal-Cereal	**No-Till is recommended**	**4**
	4. Pasture-Cereal	***No-Till is not recommended** ***(When converting pasture to cereals, it is recommended to sow an intermediate crop)**	**4**
Availability of Chemicals herbicides	**1. Available**	**No-Till is recommended**	**5**
	2. Not available	**No-Till is not recommended**	**5**
Availability of No-Till Drill	**1. Available**	**No-Till is recommended**	**6**
	2. Not available	**No-Till is not recommended**	**6**

Reference(s)

1. Lal (1979); Blevins (1984)

2 Griffith *et al,* (1973); Lal (1979); Ross and Wilson (1983); Lal (1985)

3. Pottinger *et al,* (1993); Choudhary and Baker (1984); Barr (1986); Baker *et al,* (1996)

4. Pottinger *et al,* (1993); Choudhary and Baker (1994); Praat (1995); Baker *at al,* (1996)

5. Conacher and Jeanette (1986); Unger and Skidmore (1994); Baker *et al,* (1996)

6. Phillips (1984); Throckmorton (1986); Baker *et al,* (1996)

Similarly, Table 18 was used to make certain that in the New Zealand situation, No-Till is not recommended if any of the following conditions apply:

1. If soil texture is clayey (not well drained).

2. For growing pasture after a cereal crop, as an sowing of an intermediate crop is recommended.

3. If requisite weed control chemicals are not available.

4. If farmer does not have access to a No-Till drill.

Thus, the first requirement of validation of an ES that included correctness, consistency and completeness of the inference rules was achieved by using such tables. The knowledge mentioned in these rules was extracted from relevant literature and a reference is made available at an appropriate place while NOTE is in operation. On request, NOTE brings the relevant reference onto the computer screen (Figure 17). More detailed references are available in NOTE user's guide. However, to access on-the spot literature, relevant file can be accessed by pressing few appropriate buttons in NOTE application.

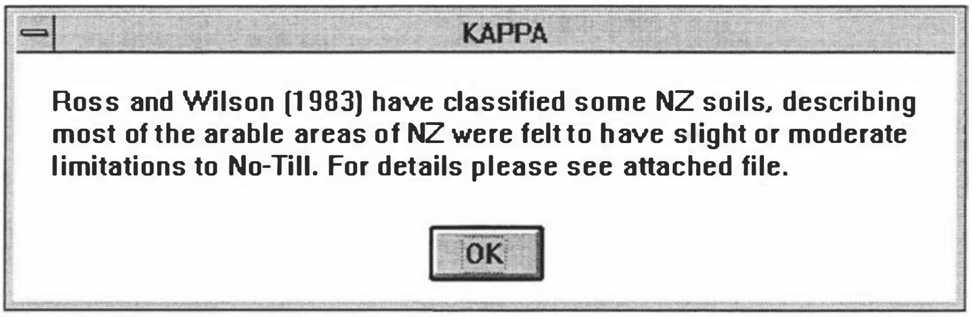

Figure 17 Reference is prompted on screen

7.3 Validation of other parameters used in designing NOTE

Tables 19 and 20 were also created to complete the validation process of NOTE. The values mentioned in Tables 19 and 20 do not have any direct impact on the outcome of the recommendation, however, these values in-directly contribute in the tillage selection process in NOTE. Tables 19 and 20 ensure that NOTE recommendation on acceptance or rejection of No-Till is in conjunction with other factors mentioned in Table 17 and Table 18. In other words, the factors mentioned in these tables are not independent during the decision making process of NOTE, and some input values from factors mentioned in Tables 17 and 18 are needed to make a recommendation. During the decision making process, if any of these values is chosen independently, and a recommendation is sought, NOTE gives an appropriate recommendation under the given circumstances, though adds a statement that more data are needed for a better recommendation. For example, in Table 19, both, No-Till or conventional tillage techniques could be recommended if straw residue was removed or left onto the surface. However, No-Till is encouraged, once farmer has access to a No-Till drill capable of penetrating into the straw left on the surface (Figure 18).

Table 19 List of factors contributing in-directly in the acceptance or rejection of No-Till

Factors	*Values*	*Result*	*Reference(s)*
Straw residue management	**1. Removed** **2. Left on the surface**	**No-Till/Conventional both are fine** ***No-Till/Conventional both are fine** ***(Subject to availability of a No-Till drill that can penetrate into the straw residue)**	**1** **1**
Soil moisture	**1. Moist or wetter** **2. Dry**	**No-Till is recommended** ***No-Till/Conventional both are fine** ***(Subject to availability of a No-Till drill that place seed into the moist underlying soil)**	**2** **2**
Soil slope	**1. Low (<5%)** **2. Medium (5-12%)** **3. High (>12%)**	**No-Till/Conventional both are fine** **No-Till/Conventional both are fine** ***No-Till is recommended** **(In greater slopes No-Till is highly recommended)**	**3** **3** **3**
Rice variety (Pakistani situation)	**1. Early maturing** **2. Mid maturing** **3. Late maturing**	**No-Till/Conventional both are fine** **No-Till/Conventional both are fine** ***No-Till is recommended** ***(No-Till is recommended to overcome the delay of planting wheat after harvesting of a late maturing rice variety)**	**4** **4** **4**

Reference(s)

1. Hyde *et al*, (1987); Saxton (1990); Riley *et al*, (1994)

2. Griffith *et al,* (1973); Phillips (1986); Ekeberg (1987); Vyn *et al,* (1994); Baker *et al,* (1996)
3. Allmaras *et al,* (1980); Blevins (1984);
4. Hobbs (1985); Aslam *et al,* (1991); Arshad *et al,* (1991)

Table 20 List of factors contributing in-directly in the acceptance or rejection of No-Till

Factors	*Values*	*Result*	*Reference(s)*
Tractor power	**1. 45-70 HP**	**No-Till/Conventional both are fine**	**1**
	2. More than 70 HP	**No-Till/Conventional both are fine** (Farmers with bigger tractor may also have a range of agricultural equipment. Depending upon other factors, No-Till, or conventional method, either can be adopted.)	**1**
Extension facilities	**1. Bad**	***No-Till is recommended**	**2**
	2. Good	**No-Till/Conventional both are fine** *(In conjunction with other factors if they also favour No-Till)	**2**

Reference(s)

1. Ekeberg (1988); Riley *et al,* (1994); Baker *et al,* (1996)
2. Thomas *et al,* (1984); Van Den Ban and Hawkins (1988); Butorac (1994)

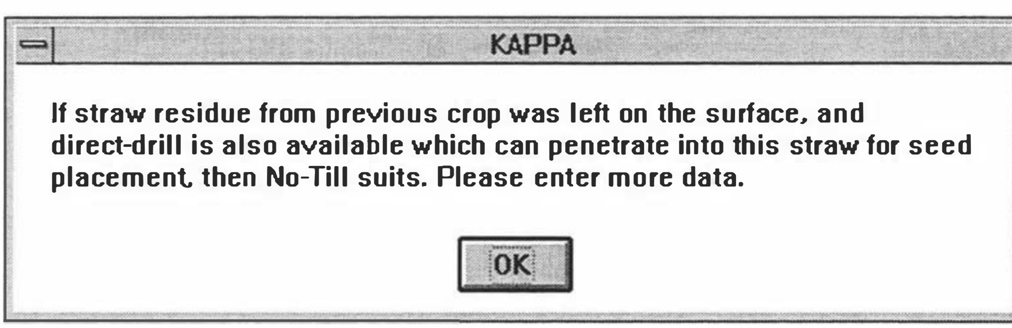

Figure 18

Soil slope is also another factor when both No-Till or conventional tillage techniques are considered suitable against various slopes. However, the recommendation is narrowed once other factors from Table 17 or Table 18 are also placed. As mentioned earlier in the straw residue example, the various slope values may also give appropriate recommendations once asked at an individual level. For example, if selected soil slope is either "Low (<5%)" or "Medium (5-12%)", No-Till or conventional tillage are both considered suitable. However, if soil slope is "High (>12%)", the recommendation reads as under (Figure 19):

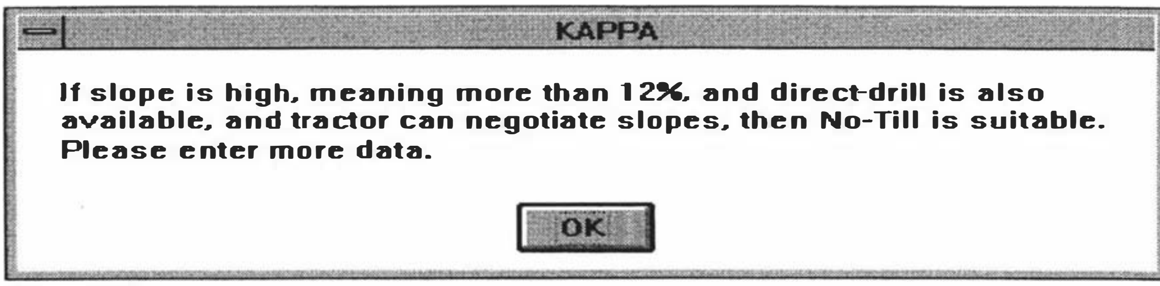

Figure 19

Once a recommendation on a suitable tillage technique is made, NOTE then identifies a suitable No-Till drill under the given conditions. Table 21 was created to validate and ensure consist recommendation from NOTE for choosing the appropriate No-Till drill in the selected soil conditions. Section 5.6.1.1 contains further details on the subject.

Table 21 List of factors contributing for selection of a No-Till drill

Factors	*Result*
Soil having medium (orange-turnip sized) stones	Light drills with spring tine legs and limited depth control winged or hoe openers are suitable in such soils.
Soil having large stones	Heavy duty No-Till drills with parallel floating drag arms having winged openers are suitable in such soils.
Bare soil	Light or heavy duty drills with spring tine legs, floating arms, and limited depth control having winged or hoe openers are suitable in such soils.
Lying residue	Conventional drills with arms or any heavy duty No-Till drill with floating arms are suitable in lying residue.
Standing stubble	Light or heavy duty No-Till drills with parallel floating arms having winged or hoe openers are suitable in such soils.

7.4 Face validation

Two human experts were approached to assess the results of NOTE. Each expert was given 10 various scenarios as shown in Table-22. Their assessments were compared with the output of the ES for the same conditions. These experts (Expert-1[1] and Expert-2[2]) were subject specialists and were not involved in the development of NOTE.

Table-22 Ten different scenarios given to two different experts

Scenarios / Parameters	1	2	3	4	5	6	7	8	9	10
i	1	1	1	2	2	2	2	1	1	1
ii	1	1	1	2	2	1	1	2	2	2
iii	1	1	1	3	2	2	1	3	3	3
iv	1	2	2	2	1	1	1	2	2	1
v	1	1	2	2	1	1	1	2	2	1
vi	1	1	1	2	2	1	1	1	2	1
vii	1	2	2	1	3	1	1	1	1	1
viii	2	1	2	1	2	1	1	1	1	1
xi	1	1	3	3	2	1	1	2	2	3
x	1	2	2	1	1	1	1	2	1	1

i = Crop to be grown; 1 = Pasture; 2 = Any cereals; ii = Harvested crop; 1 = Pasture; 2 = Any cereals; iii = Soil texture; 1 = Sandy; 2 = Silt Loam; 3 = Clayey; iv = Availability of No-Till Drill; 1 = Yes; 2 = No; v = Availability of pesticides and herbicides chemicals; 1 = Yes; 2 = No; vi = The condition of previous straw residue; 1 = Left on surface; 2 = Removed; vii = The slope of the field; 1 = Low (<5); 2 = Medium (5-12%); 3 = High (> 12%); viii = The soil moisture at the time of planting; 1 = Dry; 2 = Moist; ix = The level of extension facilities; 1 = Excellent; 2 = Good; 3 = Bad x = Tractor power range; 1 = 45-70HP; 2 = > 70HP

Table-23 Summary of the expert's results when validating NOTE

	Agreed	Did not agree	No-Till	Conventional Tillage
Expert-1	10	Nil	5	5
Expert-2	9	1	4	6
Total	19	1	9	11

Table-23 summarises the results of the experts' opinion and NOTE's recommendations. Interestingly, almost half the recommendations were in favour and half of them were against

1. Expert-1 is a ex-lecturer at Massey University. Author/co-author of 2-books, 1 book chapter, 20 scientific papers and 30 popular press articles on No-Till. Expert-1 has conducted six national and international consultancies on no-tillage equipment development and technology transfer.

2. Expert-2 holds a Master degree in Applied Science from Massey University, his thesis was on "The effects date of sowing on pasture establishment by no-tillage". Expert-2 is currently employed as a Pasture Advisor for AgResearch Grassland, Palmerston North, New Zealand.

adoption of No-Till technique. That showed that the input values, though randomly selected, were fairly chosen. All recommendations from Expert-1 matched with the recommendations made by NOTE. However, Expert-2 disagreed with NOTE on one scenario (Scenario No. 10) when the expert recommended to continue with the conventional tillage technique. In his opinion when extension facilities were not good enough (bad), No-Till should not be adopted. Therefore in his separate note, Expert-2 described that "I have recommended cultivation as the *desired option*[a] mentions the lack of extension facilities. Irrespective of that fact all other parameters tend to support the use of No-Till". His views were in fact the same as reported by Choudhary and Baker (1994) (section 6.23) namely that the success of No-Till will remain limited until professionally skilled consultants were available in sufficient numbers to give individual advice in the field. It may be clarified here that NOTE would have also produced the same recommendation, (rejection of No-Till) if it was asked to seek recommendation with only this input value. However, as NOTE gives more priority (see section 2.6.3) to factors such as soil type, availability of chemicals, and No-Till seed-drill, it recommended No-Till in this scenario as 9 other parameters were in favour of adopting No-Till.

As 19 out of 20 recommendations from two experts were the same as that of NOTE, it showed that validation procedures adopted to secure consistent and correct recommendations from NOTE were satisfactory.

a = Means that out of three levels of extension facilities available in NOTE (see Table-22), the chosen option in this scenario indicated that the level of extension facilities were not good.

Chapter-8 Summary and Conclusion

There has always been a need to ensure that more up-to-date information was available to extension agents and farmers to assist them in selecting an appropriate tillage method appropriate to their farming conditions. The move towards expert systems is an important development in the computer information technology. Expert systems help farmers to choose the better option from a wider range of possible alternatives by processing data from a large number of variables according to some validated rules constructed through research and the experiences of experts in the relevant field.

Researchers have predicted that agricultural extension agents will be affected and their future will depend on their ability to use computer technology. Currently with the advancement in communication through computers, web pages, and the availability of computer-based ES, it is now possible that ES may take the role of providing efficient farm advisory services. This study was aimed to design an ES for the non-experts seeking advice on whether to apply No-Till in a particular situation, and to disseminate knowledge on crop establishment to non-experts, farmers and to the extension agents.

Research programs have identified new technologies needed for No-Till, which has resulted in a rapid rate of adoption. For example, in the mid-eighties, Triplett and Sprague (1986) estimated that about 2% of the cropland (2.23 million ha) of annual and winter annual crops in the USA was under No-Till cultivation in 1974, with the anticipation that 45% (62 million ha) would be under No-Till by the year 2000. Latest estimates by Lessiter, (1997) have confirmed earlier predictions. No-Till is now practiced on 42% of all area under conservation tillage, and is 15.1% of all area farmed in 1996 in the USA.

Introduction of this technology requires careful evaluation of problems, including those that may be associated with its properties, available machinery, crop type and rotation plan, straw residue, climatic conditions, social constraints, management strategies and farmers' educational and awareness levels.

Therefore, the No-Till Expert System (NOTE) is designed to aid farmers and extension workers in their decision-making process. NOTE currently contains information and rules relating to rice-wheat, and cotton-wheat crop rotations in Pakistan. Over-drilling pasture, and related crop establishment data from New Zealand conditions has also been incorporated. By incorporating more data and information, the ES can possibly be used for many crop-rotations and locations. If this current work is continued on a wider scale, it is anticipated that by combining the knowledge how tillage affects the parameters and processes of crop establishment, the non-experts and the extension agents will be capable of evaluating different tillage systems through computers. Therefore, this study will eventually contribute towards long-term dissemination of agricultural knowledge.

NOTE is designed to extend the decision maker's capabilities and not to replace their managerial judgement. The interactive capabilities and its convenience allow non-experts to exert more control over the application of No-Till technology before accepting or rejecting its adoption. Thus, NOTE is meant to be an assistant to the decision makers.

NOTE requires the user to input information on various parameters influencing the decision making process of either choosing or rejecting No-Till. Guidance in selecting appropriate values is provided and these values are placed in the given dialogue boxes. From the literature, this study has pooled information concerning factors affecting the choice of No-Till technique, and has converted the straight "English like sentences" into the **IF** and **THEN** computer language before incorporating these rules in the NOTE. NOTE after reading all 472 rules recommends either to accept or reject No-Till technique under the selected conditions.

NOTE contains IF and THEN language rules on soil texture, soil slope, crop rotation, the condition of straw residue, availability of chemicals, and the availability of No-Till seed-drill. Environmental, local legislation, soil erosion, and social aspects were also considered, but were not incorporated in the final design because of lack of the available quantitative data on these issues.

Verification and validation of NOTE was done during and after its development. Verification process ensured that NOTE provided consistent recommendations. However, for validating NOTE human experts were engaged. 10 various scenarios were given to two subject specialists who were not involved in its development stage. The recommendations from the human experts and those from NOTE were compared. 19 out of 20 results matched.

Based on this study and numerous meeting with the extension staff at Pakistan Agricultural Research Council, Islamabad, a model of technology change was established for introducing No-Till in Pakistan. The use of NOTE was considered a useful tool for selecting farmers in a pilot area. The expected feedback would further improve NOTE's capabilities, as it updating facilities permit to incorporate any number of rules and information into it.

Based on somewhat limited validation of NOTE, the study indicated that:

1. A tillage expert system can be designed by using a shell (without knowing a computer language).
2. Knowledge can be successfully taken from the written form, converted into ***english-like sentences*** (rules), and combined into an ES. The recommendations produced by adopting such procedures were consistent with the recommendations made by the subject specialists.
3. One ES can work at various locations and crops provided relevant local information and data is incorporated and the rules are edited accordingly.
4. During the development stage of NOTE, the literature on No-Till has confirmed that under the following situations No-Till is not suitable:
   - If the soil texture is heavy and not well drained.
   - If requisite herbicides and pesticides are not available.
   - If the area is affected by rice stem borer, and the requisite pesticides are not available (under Pakistani situation).

- If growing cereal after pasture, sowing of an intermediate crop is recommended under New Zealand conditions because of possible transfer of Argentine stem weevil.
- If No-Till drill is not accessible.

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Appendices

List of Appendices

1. Appendix-Rules
2. Appendix User's Guide on NOTE

```
/*****************************************************/
/**      ALL RULES ARE SAVED BELOW        **/
/*****************************************************/
```

Rules from File: Country.kal

```
 /*****************************************************/
/**      ALL RULES ARE SAVED BELOW        **/
/*****************************************************/
    /***********************************
     **** RULE: Pakistan
     ***********************************/
MakeRule( Pakistan, [x|ExpertSystem],
   x:CropRotation #= Pakistan,
   Execute( kappa, Pakistan.kal ) );
    /***********************************
     **** RULE: NewZealand
     ***********************************/
MakeRule( NewZealand, [x|ExpertSystem],
   x:CropRotation #= NewZealand,
   Execute( kappa, NZ.kal ) );
```

Rules from File: Pakistan.kal

```
    /***********************************
     **** RULE: CR1
     ***********************************/
MakeRule( CR1, [x|ExpertSystem],
   x:CropRotation #= Rice,
   Execute( kappa, pkr.kal ) );
    /***********************************
     **** RULE: CR2
     ***********************************/
MakeRule( CR2, [x|ExpertSystem],
   x:CropRotation #= Wheat,
   Execute( kappa, pkw.kal ) );
    /***********************************
     **** RULE: CR3
     ***********************************/
MakeRule( CR3, [x|ExpertSystem],
   x:CropRotation #= Cotton,
   Execute( kappa, pkc.kal ) );
```

Rules from File: NZ.kal

```
    /***********************************
     **** RULE: CR1
     ***********************************/
```

```
MakeRule( CR1, [x|ExpertSystem],
   x:CropRotation #= Cereals,
   Execute( kappa, nzc.kal ) );
     /************************************
      **** RULE: CR2
      ************************************/
MakeRule( CR2, [x|ExpertSystem],
   x:CropRotation #= Pasture,
   Execute( kappa, nzp.kal ) );
```

Rules from File: NZC.kal

```
/************************************
      **** RULE: Rule2
      ************************************/
MakeRule( Rule2, [x|NewZealand],
   ( x:Grow #= Pasture And x:Harvested #= "Any cereals" )
      And ( x:Harvested #= "Any cereals" ) And ( x:Soil #= Clayey )
      And ( x:Drill #= "Not Available" ) And ( x:Chemicals #=
                                           "Not Available" )
      And ( x:Harvesting #= Removed ) And ( x:Moisture #= Dry )
      And ( x:TTransfer #= Bad ) And ( x:Tractor #= "More than 70HP" )
      And ( x:Slope #= "Low(<5%)" ),
   PostMessage( "The given condition(s) suggest that farmer should continue with
conventional-Tillage techniques.  For further details please press button <Please
explain> and read appropriate explanation. [2]" ) );

     /************************************
      **** RULE: Rule4
      ************************************/
MakeRule( Rule4, [x|NewZealand],
   ( x:Drill #= "Not Available" ) Or ( x:Chemicals #= "Not Available" )
      Or ( x:TTransfer #= Bad ),
   PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques.  For further details please press button <Please
explain> and read appropriate explanation. [4]" ) );

     /************************************
      **** RULE: Rule3
      ************************************/
MakeRule( Rule3, [x|NewZealand],
   ( x:Harvested #= "Any cereals" And x:Grow #= "Any cereals" )
      Xor ( x:Harvested #= "Any cereals" And x:Grow #= Pasture )
      Xor ( x:Harvested #= Pasture And x:Grow #= "Any cereals" )
      Xor ( x:Harvested #= Pasture And x:Grow #= Pasture )
      Xor ( x:Grow #= Pasture And x:Harvested #= Pasture )
      Xor ( x:Grow #= Pasture And x:Harvested #= "Any cereals" )
      Xor ( x:Grow #= "Any cereals" And x:Harvested #= Pasture )
```

```
    Xor ( x:Grow #= "Any cereals" And x:Harvested #= "Any cereals" )
    Xor ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
    Xor ( x:Drill #= Available ) Xor ( x:Chemicals #= Available )
    Xor ( x:Harvesting #= "Left on surface" Or x:Harvesting
          #= Removed ) Xor ( x:TTransfer #= Excellent
                             Or x:TTransfer #= Good
                             Or x:TTransfer #= Bad )
    Xor ( x:Tractor #= "Range 45-70HP" Or x:Tractor #= "More than 70HP" )
    Or ( x:Slope #= "Low(<5%)" Or x:Slope #= "Medium(5-12%)" Or
         x:Slope #= "High(>12%)" ),
  PostMessage( "Under the selected conditions, No-Till suits. For further details please
press button <Please explain> and read appropriate explanation. [3]" ) );

   /************************************
    **** RULE: Rule1
    ************************************/
MakeRule( Rule1, [x|NewZealand],
  ( x:Grow #= Pasture ) And ( x:Harvested #= Pasture )
    And ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
    And ( x:Drill #= Available ) And ( x:Chemicals #= Available )
    And ( x:Harvesting #= "Left on surface" ) And ( x:Moisture
                                             #= Moist )
    And ( x:TTransfer #= Excellent Or x:TTransfer #= Good )
    And ( x:Tractor #= "Range 45-70HP" ) And ( x:Slope #= "Medium(5-10%)"
                                     Or x:Slope
                                     #= "High(>10%)" ),
  PostMessage( "Under the selected conditions, No-Till suits. For further details please
press button <Please explain> and read appropriate explanation. [1]" ) );

   /************************************
    **** RULE: SoilCons
    ************************************/
MakeRule( SoilCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Soil = "Sandy Or Silt Loam Or Well drained Clayey, and Well drained soils coming
out of pasture";
  PostMessage( "The soil texture should to be either ", x:Soil );
  } );

   /************************************
    **** RULE: SoilConv
    ************************************/
MakeRule( SoilConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Soil = "Clayey and undrained clayey soils";
  PostMessage( "The soil texture seems to be ", x:Soil );
```

```
} );

  /************************************
   **** RULE: GrowCons
   ************************************/
MakeRule( GrowCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Grow = "renew pasture, or grow cereals or fodder in rotation";
  PostMessage( "The  farmer either wishes to ", x:Grow );
  } );

  /************************************
   **** RULE: GrowConv
   ************************************/
MakeRule( GrowConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Grow = " intermediate crop (fodder) to avoid pest transfer";
  PostMessage( "Farmer should sow an ", x:Grow );
  } );

  /************************************
   **** RULE: DrillCons
   ************************************/
MakeRule( DrillCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Drill = Available;
  PostMessage( "The No-Till  drill should be  ", x:Drill );
  } );

  /************************************
   **** RULE: DrillConv
   ************************************/
MakeRule( DrillConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Drill = "Not Available";
  PostMessage( "The No-Till  drill seems to be  ", x:Drill );
  } );

  /************************************
   **** RULE: TractorCons
   ************************************/
MakeRule( TractorCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
```

```
   x:Tractor = "Range 45-70HP";
   PostMessage( "Tractor power available should  ", x:Tractor );
   } );

     /************************************
      ****  RULE: TractorConv
      ************************************/
MakeRule( TractorConv, [x|NewZealand],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Tractor = "More than 70HP, and it also seems that there is no access to a direct-
drill ";
  PostMessage( "Tractor available power seems to be ", x:Tractor );
   } );

     /************************************
      ****  RULE: TTransferCons
      ************************************/
MakeRule( TTransferCons, [x|NewZealand],
   x:Tillage #= "No-Till",
   {
   x:TTransfer = "Excellent Or Good";
   PostMessage( "The level of extension facilities should be either ",
      x:TTransfer );
   } );

     /************************************
      ****  RULE: TTransferConv
      ************************************/
MakeRule( TTransferConv, [x|NewZealand],
   x:Tillage #= "Conventional-Tillage",
   {
   x:TTransfer = Bad;
   PostMessage( "The level of extension facilities available is rated as  ",
      x:TTransfer );
   } );

     /************************************
      ****  RULE: ChemicalsCons
      ************************************/
MakeRule( ChemicalsCons, [x|NewZealand],
   x:Tillage #= "No-Till",
   {
   x:Chemicals = Available;
   PostMessage( "The herbicides chemical should be   ", x:Chemicals );
   } );
```

```
/***********************************
 **** RULE: ChemicalsConv
 ***********************************/
MakeRule( ChemicalsConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Chemicals = "Not  available";
  PostMessage( "The required herbicides chemicals seem  to be ",
     x:Chemicals );
  } );

/***********************************
 **** RULE: HarvestingCons
 ***********************************/
MakeRule( HarvestingCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Harvesting = "Left on surface, and direct-drill seems available";
  PostMessage( "The previous crop residue seems to be  ", x:Harvesting );
  } );

/***********************************
 **** RULE: HarvestingConv
 ***********************************/
MakeRule( HarvestingConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvesting = "been removed and direct-drill seems not available";
  PostMessage( "From  previous crop residue should have been ",
     x:Harvesting );
  } );
/***********************************
 **** RULE: MoistureCons
 ***********************************/
MakeRule( MoistureCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Moisture = "Moist or Wetter";
  PostMessage( "The soil around seed micro environment should be either ",
     x:Moisture );
  } );

/***********************************
 **** RULE: MoistureConv
 ***********************************/
MakeRule( MoistureConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
```

```
   x:Moisture = "Dry and suitable direct-drill also not available";
   PostMessage( "The soil around micro-environment seems to be ",
      x:Moisture );
   } );

     /************************************
      **** RULE: HarvestedCons
      *************************************/
MakeRule( HarvestedCons, [x|NewZealand],
   x:Tillage #= "No-Till",
   {
   x:Harvested = "renew pasture, or grow cereals or fodder in rotation";
   PostMessage( "The  farmer seems to ", x:Harvested );
   } );

     /************************************
      **** RULE: HarvestedConv
      *************************************/
MakeRule( HarvestedConv, [x|NewZealand],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Harvested = "a cereal crop, or should sow an intermediate crop (fodder) may be
sown to avoid pest transfer";
   PostMessage( "Farmer seems to have harvested ", x:Harvested );
   } );

     /************************************
      **** RULE: SlopeCons
      *************************************/
MakeRule( SlopeCons, [x|NewZealand],
   x:Tillage #= "No-Till",
   {
   x:Slope = "Medium(5-12%) Or in case if >12%, then tractor should be able to
negotiate slopes";
   PostMessage( "The slope of  the field should be either ", x:Slope );
   } );

     /************************************
      **** RULE: SlopeConv
      *************************************/
MakeRule( SlopeConv, [x|NewZealand],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Slope = "flat, (lower than 5% and direct-drill seems not available";
   PostMessage( "Slope of  the field  seems to be ", x:Slope );
   } );
```

```
/************************************
 **** RULE: CerealPasture
 ************************************/
MakeRule( CerealPasture, [x|NewZealand],
   ( x:Harvested #= "Any cereals" ) And ( x:Grow #= Pasture ),
   PostMessage( "When converting cereals to pasture production, No-Till is not
suitable. Please enter  more data for a better recommendation" ) );

/************************************
 **** RULE: SoilLoam
 ************************************/
MakeRule( SoilLoam, [x|NewZealand],
   ( x:Soil #= Sandy ) Or ( x:Soil #= "Silt Loam" ),
   PostMessage( "Sandy to Sandy Loam and Silt Loam soils are suited to No-Till. Well
drained soils coming out of pasture are also suitable for No-Till cropping.  More data
are required for  better recommendation." ) );

/************************************
 **** RULE: CerealCereal
 ************************************/
MakeRule( CerealCereal, [x|NewZealand],
   ( x:Harvested #= "Any cereals" ) And ( x:Grow #= "Any cereals" ),
   PostMessage( "When growing cereals or fodder in rotation, No-Till can be employed.
However, more data are required to get a better recommendation." ) );

/************************************
 **** RULE: SoilClayey
 ************************************/
MakeRule( SoilClayey, [x|NewZealand],
   x:Soil #= Clayey,
   PostMessage( "Undrained clayey soils are not suitable for adoption of No-Till.
However, if drained, could be suitable for No-Till. Please enter more data for a better
recommendation." ) );

/************************************
 **** RULE: StrawLeft
 ************************************/
MakeRule( StrawLeft, [x|NewZealand],
   x:Harvesting #= "Left on surface",
   PostMessage( "If straw residue from previous crop was left on surface, and direct-
drill is available then No-Till is suitable. Please enter more data." ) );

/************************************
 **** RULE: StrawRemoved
 ************************************/
MakeRule( StrawRemoved, [x|NewZealand],
   x:Harvesting #= Removed,
```

```
   PostMessage( "If straw residue from previous crop was removed, and direct drill is
available, and seed micro-environment is moist, No-Till is suitable. Please enter more
data." ) );

     /***********************************
      ****  RULE: MoistureDry
      ***********************************/
MakeRule( MoistureDry, [x|NewZealand],
   x:Moisture #= Dry,
   PostMessage( "If the soil around seed micro-environment is dry, and no suitable
direct-drill is available for seeding, then conventional tillage suits. Please enter more
data." ) );

     /***********************************
      ****  RULE: MoistureMoist
      ***********************************/
MakeRule( MoistureMoist, [x|NewZealand],
   x:Moisture #= Moist,
   PostMessage( "If the soil around seed micro-environment is moist or wetter, and a
suitable direct-drill is also available for seeding, then No-Till suits.  Please enter more
data." ) );

     /***********************************
      ****  RULE: SlopeMedium
      ***********************************/
MakeRule( SlopeMedium, [x|NewZealand],
   x:Slope #= "Medium(5-12%)",
   PostMessage( "If slope is medium, meaning 5 to 12%, and a direct-drill is also
available, No-Till is more suitable. However, more data are needed for a better
recommendation." ) );

     /***********************************
      ****  RULE: SlopeHigh
      ***********************************/
MakeRule( SlopeHigh, [x|NewZealand],
   x:Slope #= "High(>12%)",
   PostMessage( "If slope is high, meaning more than 12%, and a direct-drill is also
available, and tractor can negotiate slopes, then No-Till is suitable. More data are
needed for a better recommendation." ) );

     /***********************************
      ****  RULE: SlopeLow
      ***********************************/
MakeRule( SlopeLow, [x|NewZealand],
   x:Slope #= "Low(<5%)",
   PostMessage( "If field is flat, or slope is lower than 5%, and No-Till drill is also
available, No-Till or Conventional-Tillage both are suitable. However, more data are
needed for a better recommendation." ) );
```

```
/************************************
 **** RULE: TTGood
 ************************************/
MakeRule( TTGood, [x|NewZealand],
   x:TTransfer #= Excellent Or x:TTransfer #= Good,
   PostMessage( "If local agricultural extension services are good in providing
information w.r.t. using appropriate pesticides, herbicides etc., then No-Till suits. More
data are needed for a better recommendation." ) );

/************************************
 **** RULE: DrillAvail
 ************************************/
MakeRule( DrillAvail, [x|NewZealand],
   x:Drill #= Available,
   PostMessage( "If farmer has access to a direct drill which can work in local
conditions, and can penetrate into straw residue (if left), No-Till suits. Please enter more
data." ) );

/************************************
 **** RULE: DrillNotAvail
 ************************************/
MakeRule( DrillNotAvail, [x|NewZealand],
   x:Drill #= "Not Available",
   PostMessage( "If farmer has not any access to a direct drill, conventional tillage
methods suit. However, please enter more data for a better recommendation." ) );

/************************************
 **** RULE: ChemicalsAvail
 ************************************/
MakeRule( ChemicalsAvail, [x|NewZealand],
   x:Chemicals #= Available,
   PostMessage( "If appropriate pesticides and herbicides are available, and all other
factors also favour, No-Till suits. Please enter more data for a better recommendation."
) );

/************************************
 **** RULE: ChemicalsNotAvail
 ************************************/
MakeRule( ChemicalsNotAvail, [x|NewZealand],
   x:Chemicals #= "Not Available",
   PostMessage( "If appropriate pesticides and herbicides are not available conventional
tillage methods suit. Please enter more data for a better recommendation." ) );

/************************************
 **** RULE: TractorSmall
 ************************************/
MakeRule( TractorSmall, [x|NewZealand],
   x:Tractor #= "Range 45-70HP",
```

```
   PostMessage( "Farmers having tractors 45-70HP range, are generally those who have
low land holdings capacity. These are the farmers who need to adopt No-Till." ) );

     /************************************
      **** RULE: TractorLarge
      ************************************/
MakeRule( TractorLarge, [x|NewZealand],
   x:Tractor #= "More than 70HP",
   PostMessage( "Farmers with bigger tractors may also have other range of agricultural
equipment for their large land holdings. No-Till or Conventional methods both can be
suitable depending upon other factors." ) );

     /************************************
      **** RULE: GrowCom1
      ************************************/
MakeRule( GrowCom1, [x|NewZealand],
   x:GrowCom #= Yes,
   Execute( "C:\kappa\nzrocom.doc" ) );

     /************************************
      **** RULE: GrowCom2
      ************************************/
MakeRule( GrowCom2, [x|NewZealand],
   x:GrowCom #= No,
   ShowWindow( Comments ) );

     /************************************
      **** RULE: SoilCom1
      ************************************/
MakeRule( SoilCom1, [x|NewZealand],
   x:SoilCom #= Yes,
   Execute( "C:\kappa\nzsocom.doc" ) );

     /************************************
      **** RULE: SoilCom2
      ************************************/
MakeRule( SoilCom2, [x|NewZealand],
   x:SoilCom #= No,
   ShowWindow( Comments ) );

     /************************************
      **** RULE: MoistureCom1
      ************************************/
MakeRule( MoistureCom1, [x|NewZealand],
   x:MoistureCom #= Yes,
   Execute( "C:\kappa\nzmocom.doc" ) );
```

```
  /************************************
   **** RULE: MoistureCom2
   ************************************/
MakeRule( MoistureCom2, [x|NewZealand],
  x:MoistureCom #= No,
  ShowWindow( Comments ) );
  /************************************
   **** RULE: HarvestingCom1
   ************************************/
MakeRule( HarvestingCom1, [x|NewZealand],
  x:HarvestingCom #= Yes,
  Execute( "C:\kappa\nzharcom.doc" ) );

  /************************************
   **** RULE: HarvestingCom2
   ************************************/
MakeRule( HarvestingCom2, [x|NewZealand],
  x:HarvestingCom #= No,
  ShowWindow( Comments ) );

  /************************************
   **** RULE: SlopeCom1
   ************************************/
MakeRule( SlopeCom1, [x|NewZealand],
  x:SlopeCom #= Yes,
  Execute( "C:\kappa\nzslpcom.doc" ) );

  /************************************
   **** RULE: SlopeCom2
   ************************************/
MakeRule( SlopeCom2, [x|NewZealand],
  x:SlopeCom #= No,
  ShowWindow( Comments ) );

  /************************************
   **** RULE: ChemicalsCom1
   ************************************/
MakeRule( ChemicalsCom1, [x|NewZealand],
  x:ChemicalsCom #= Yes,
  Execute( "C:\kappa\nzchcom.doc" ) );

  /************************************
   **** RULE: ChemicalsCom2
   ************************************/
MakeRule( ChemicalsCom2, [x|NewZealand],
  x:ChemicalsCom #= No,
  ShowWindow( Comments ) );
```

```
/************************************
 **** RULE: TTCom1
 ************************************/
MakeRule( TTCom1, [x|NewZealand],
   x:TTCom #= Yes,
   Execute( "C:\kappa\nzttcom.doc" ) );

/************************************
 **** RULE: TTCom2
 ************************************/
MakeRule( TTCom2, [x|NewZealand],
   x:TTCom #= No,
   ShowWindow( Comments ) );

/************************************
 **** RULE: TractorCom1
 ************************************/
MakeRule( TractorCom1, [x|NewZealand],
   x:TractorCom #= Yes,
   Execute( "C:\kappa\nztrcom.doc" ) );

/************************************
 **** RULE: TractorCom2
 ************************************/
MakeRule( TractorCom2, [x|NewZealand],
   x:TractorCom #= No,
   ShowWindow( Comments ) );

/************************************
 **** RULE: DrillCom1
 ************************************/
MakeRule( DrillCom1, [x|NewZealand],
   x:DrillCom #= Yes,
   Execute( "C:\kappa\nzdrcom.doc" ) );

/************************************
 **** RULE: DrillCom2
 ************************************/
MakeRule( DrillCom2, [x|NewZealand],
   x:DrillCom #= No,
   ShowWindow( Comments ) );

/************************************
 **** RULE: PastureCereal
 ************************************/
MakeRule( PastureCereal, [x|NewZealand],
   ( x:Harvested #= Pasture ) And ( x:Grow #= "Any cereals" ),
```

PostMessage("When converting pasture to cereals production, it is recommended to sow an intermediate crop such as fodder to avoid pest transfer. However, more data is required to get a better recommendation."));

```
/************************************
 **** RULE: PasturePasture
 ************************************/
MakeRule( PasturePasture, [x|NewZealand],
   ( x:Harvested #= Pasture ) And ( x:Grow #= Pasture ),
   PostMessage( "Pasture renewal is commonly practiced in New Zealand by over-drilling. However, more data are required for a better recommendation." ) );

/************************************
 **** RULE: TTBad
 ************************************/
MakeRule( TTBad, [x|NewZealand],
   x:TTransfer #= Bad,
   PostMessage( "If extension services are not well aware of information on using appropriate pesticides, herbicides etc., then conventional tillage suits. More data are needed for a better recommendation." ) );

/************************************
 **** RULE: HarvestedCereal
 ************************************/
MakeRule( HarvestedCereal, [x|NewZealand],
   x:Harvested #= "Any cereals",
   PostMessage( "Information provided is not enough. Please enter more data. Thanks." ) );

/************************************
 **** RULE: HarvestedPasture
 ************************************/
MakeRule( HarvestedPasture, [x|NewZealand],
   x:Harvested #= Pasture,
   PostMessage( "Information provided is not enough. Please enter more data. Thanks." ) );

/************************************
 **** RULE: GrowPasture
 ************************************

/MakeRule( GrowPasture, [x|NewZealand],
   x:Grow #= Pasture,   PostMessage( "Information provided is not enough. Please enter more data. Thanks." ) );

/************************************
 **** RULE: GrowCereal•
 ************************************/
```

```
MakeRule( GrowCereal, [x|NewZealand],
   x:Grow #= "Any cereals",
   PostMessage( "Information provided is not enough. Please enter more data. Thanks."
) );

     /************************************
      **** RULE: StoneMed
      *************************************/
MakeRule( StoneMed, [x|Drills],
   x:DrillTypes #= "Stone (medium) texture",
   PostMessage( "Light drills with spring tine legs and limited depth control winged or
hoe openers are suitable under such conditions" ) );

     /************************************
      **** RULE: StoneLar
      *************************************/
MakeRule( StoneLar, [x|Drills],
   x:DrillTypes #= "Stone (large) texture",
   PostMessage( "Heavy duty direct drills with parallel floating drag arms having winged
openers are suitable under such conditions" ) );

     /************************************
      **** RULE: StandStubble
      *************************************/
MakeRule( StandStubble, [x|Drills],
   x:DrillTypes #= "Standing stubble",
   PostMessage( "Light or heavy duty direct drill with parallel floating drag arms having
winged or hoe openers are suitable under such conditions" ) );

     /************************************
      **** RULE: LyingResidue
      *************************************/
MakeRule( LyingResidue, [x|Drills],
   x:DrillTypes #= "Lying residue",
   PostMessage( "Conventional drills with floating drag arms, or any heavy duty direct
drill with floating drag arms are suitable under such conditions" ) );

     /************************************
      **** RULE: BareSoil
      *************************************/
MakeRule( BareSoil, [x|Drills],
   x:DrillTypes #= "Bare soil, short pasture",
   PostMessage( "Light or heavy duty drills with spring tine legs, or floating drag arms,
and limited depth control, having winged or hoe openers are suitable under such
conditions." ) );
```

```
/************************************
 **** RULE: ConvenTill
 ************************************/
MakeRule( ConvenTill, [x|Drills],
   x:DrillTypes #= "Conventional-Tillage",
   ShowWindow( SESSION ) );
```

Rules from File: NZP.kal

```
/************************************
 **** RULE: Rule2
 ************************************/
MakeRule( Rule2, [x|NewZealand],
   ( x:Grow #= Pasture And x:Harvested #= "Any cereals" )
      And ( x:Harvested #= "Any cereals" ) And ( x:Soil #= Clayey )
      And ( x:Drill #= "Not Available" ) And ( x:Chemicals #=
                                          "Not Available" )
      And ( x:Harvesting #= Removed ) And ( x:Moisture #= Dry )
      And ( x:TTransfer #= Bad ) And ( x:Tractor #= "More than 70HP" )
      And ( x:Slope #= "Low(<5%)" ),
   PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques. For further details please press button <Please
explain> and read appropriate explanation. [2]" ) );

/************************************
 **** RULE: Rule4
 ************************************/
MakeRule( Rule4, [x|NewZealand],
   ( x:Drill #= "Not Available" ) Or ( x:Chemicals #= "Not Available" )
      Or ( x:TTransfer #= Bad ),
   PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques. For further details please press button <Please
explain> and read appropriate explanation. [4]" ) );

/************************************
 **** RULE: Rule3
 ************************************/
MakeRule( Rule3, [x|NewZealand],
   ( x:Harvested #= "Any cereals" And x:Grow #= "Any cereals" )
      Xor ( x:Harvested #= "Any cereals" And x:Grow #= Pasture )
      Xor ( x:Harvested #= Pasture And x:Grow #= "Any cereals" )
      Xor ( x:Harvested #= Pasture And x:Grow #= Pasture )
      Xor ( x:Grow #= Pasture And x:Harvested #= Pasture )
      Xor ( x:Grow #= Pasture And x:Harvested #= "Any cereals" )
      Xor ( x:Grow #= "Any cereals" And x:Harvested #= Pasture )
      Xor ( x:Grow #= "Any cereals" And x:Harvested #= "Any cereals" )
      Xor ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
      Xor ( x:Drill #= Available ) Xor ( x:Chemicals #= Available )
```

```
    Xor ( x:Harvesting #= "Left on surface" Or x:Harvesting
          #= Removed ) Xor ( x:TTransfer #= Excellent
                          Or x:TTransfer #= Good
                           Or x:TTransfer #= Bad )
    Xor ( x:Tractor #= "Range 45-70HP" Or x:Tractor #= "More than 70HP" )
    Or ( x:Slope #= "Low(<5%)" Or x:Slope #= "Medium(5-12%)" Or
          x:Slope #= "High(>12%)" ),
  PostMessage( "Under the selected conditions, No-Till suits. For further details please
press button <Please explain> and read appropriate explanation. [3]" ) );

   /***********************************
    **** RULE: Rule1
    ***********************************/
MakeRule( Rule1, [x|NewZealand],
  ( x:Grow #= Pasture ) And ( x:Harvested #= Pasture )
    And ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
    And ( x:Drill #= Available ) And ( x:Chemicals #= Available )
    And ( x:Harvesting #= "Left on surface" ) And ( x:Moisture
                                       #= Moist )
    And ( x:TTransfer #= Excellent Or x:TTransfer #= Good )
    And ( x:Tractor #= "Range 45-70HP" ) And ( x:Slope #= "Medium(5-10%)"
                                  Or x:Slope
                                  #= "High(>10%)" ),
  PostMessage( "Under the selected conditions, No-Till suits. For further details please
press button <Please explain> and read appropriate explanation. [1]" ) );

   /***********************************
    **** RULE: SoilCons
    ***********************************/
MakeRule( SoilCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Soil = "Sandy Or Silt Loam Or Well drained Clayey, and Well drained soils coming
out of pasture";
  PostMessage( "The soil texture should to be either  ", x:Soil );
  } );

   /***********************************
    **** RULE: SoilConv
    ***********************************/
MakeRule( SoilConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Soil = "Clayey and undrained clayey soils";
  PostMessage( "The soil texture seems to be  ", x:Soil );
  } );
```

```
   /************************************
    ****  RULE: GrowCons
    ************************************/
MakeRule( GrowCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Grow = "renew pasture, or grow cereals or fodder in rotation";
  PostMessage( "The  farmer either wishes to ", x:Grow );
  } );

   /************************************
    ****  RULE: GrowConv
    ************************************/
MakeRule( GrowConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Grow = " intermediate crop (fodder) to avoid pest transfer";
  PostMessage( "Farmer should sow an ", x:Grow );
  } );

   /************************************
    ****  RULE: DrillCons
    ************************************/
MakeRule( DrillCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Drill = Available;
  PostMessage( "The No-Till  drill should be  ", x:Drill );
  } );

   /************************************
    ****  RULE: DrillConv
    ************************************/
MakeRule( DrillConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
•  x:Drill = "Not Available";
  PostMessage( "The No-Till  drill seems to be  ", x:Drill );
  } );

   /************************************
    ****  RULE: TractorCons
    ************************************/
MakeRule( TractorCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Tractor = "Range 45-70HP";
  PostMessage( "Tractor power available should  ", x:Tractor );
```

```
  /************************************
   **** RULE: TractorConv
   ************************************/
MakeRule( TractorConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Tractor = "More than 70HP, and it also seems that there is no access to a direct-
drill ";
  PostMessage( "Tractor available power seems to be ", x:Tractor );
  } );

  /************************************
   **** RULE: TTransferCons
   ************************************/
MakeRule( TTransferCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:TTransfer = "Excellent Or Good";
  PostMessage( "The level of extension facilities should be either ",
     x:TTransfer );
  } );

  /************************************
   **** RULE: TTransferConv
   ************************************/
MakeRule( TTransferConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:TTransfer = Bad;
  PostMessage( "The level of extension facilities available is rated as  ",
     x:TTransfer );
  } );

  /************************************
   **** RULE: ChemicalsCons
   ************************************/
MakeRule( ChemicalsCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Chemicals = Available;
  PostMessage( "The herbicides chemical should be   ", x:Chemicals );
  } );

  /************************************
   **** RULE: ChemicalsConv
   ************************************/
MakeRule( ChemicalsConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
```

```
    x:Chemicals = "Not  available";
  PostMessage( "The required herbicides chemicals seem  to be ",
     x:Chemicals );
  } );

    /************************************
     ****  RULE: HarvestingCons
     ************************************/
MakeRule( HarvestingCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Harvesting = "Left on surface, and direct-drill seems available";
  PostMessage( "The previous crop residue seems to be  ", x:Harvesting );
  } );

    /************************************
     ****  RULE: HarvestingConv
     ************************************/
MakeRule( HarvestingConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvesting = "been removed and direct-drill seems not available";
  PostMessage( "From  previous crop residue should have been ",
     x:Harvesting );
  } );

    /************************************
     ****  RULE: MoistureCons
     ************************************/
MakeRule( MoistureCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Moisture = "Moist or Wetter";
  PostMessage( "The soil around seed micro environment should be either ",
     x:Moisture );
  } );

    /************************************
     ****  RULE: MoistureConv
     ************************************/
MakeRule( MoistureConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Moisture = "Dry and suitable direct-drill also not available";
  PostMessage( "The soil around micro-environment seems to be ",
     x:Moisture );
  } );
```

```
/***********************************
 **** RULE: HarvestedCons
 ***********************************/
MakeRule( HarvestedCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Harvested = "renew pasture, or grow cereals or fodder in rotation";
  PostMessage( "The  farmer seems to ", x:Harvested );
  } );

/***********************************
 **** RULE: HarvestedConv
 ***********************************/
MakeRule( HarvestedConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvested = "a cereal crop, or should sow an intermediate crop (fodder) may be
sown to avoid pest transfer";
  PostMessage( "Farmer seems to have harvested ", x:Harvested );
  } );

/***********************************
 **** RULE: SlopeCons
 ***********************************/
MakeRule( SlopeCons, [x|NewZealand],
  x:Tillage #= "No-Till",
  {
  x:Slope = "Medium(5-12%) Or in case if >12%, then tractor should be able to
negotiate slopes";
  PostMessage( "The slope of  the field should be either ", x:Slope );
  } );

/***********************************
 **** RULE: SlopeConv
 ***********************************/
MakeRule( SlopeConv, [x|NewZealand],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Slope = "flat, (lower than 5% and direct-drill seems not available";
  PostMessage( "Slope of  the field  seems to be ", x:Slope );
  } );

/***********************************
 **** RULE: CerealPasture
 ***********************************/
MakeRule( CerealPasture, [x|NewZealand],
  ( x:Harvested #= "Any cereals" ) And ( x:Grow #= Pasture ),
```

```
   PostMessage( "When converting cereals to pasture production, No-Till is not
suitable. Please enter  more data for a better recommendation" ) );

     /*************************************
      **** RULE: SoilLoam
      *************************************/
MakeRule( SoilLoam, [x|NewZealand],
   ( x:Soil #= Sandy ) Or ( x:Soil #= "Silt Loam" ),
   PostMessage( "Sandy to Sandy Loam and Silt Loam soils are suited to No-Till. Well
drained soils coming out of pasture are also  suitable for No-Till cropping.  More data is
required for  better recommendation." ) );

     /*************************************
      **** RULE: CerealCereal
      *************************************/
MakeRule( CerealCereal, [x|NewZealand],
   ( x:Harvested #= "Any cereals" ) And ( x:Grow #= "Any cereals" ),
   PostMessage( "When growing cereals or fodder in rotation, No-Till can be employed.
However, more data are required to get a better recommendation." ) );

     /*************************************
      **** RULE: SoilClayey
      *************************************/
MakeRule( SoilClayey, [x|NewZealand],
   x:Soil #= Clayey,
   PostMessage( "Undrained clayey soils are not suitable for adoption of No-Till.
However, if drained, could be suitable for No-Till. Please enter more data for a better
recommendation." ) );

     /*************************************
      **** RULE: StrawLeft
      *************************************/
MakeRule( StrawLeft, [x|NewZealand],
   x:Harvesting #= "Left on surface",
   PostMessage( "If straw residue from previous crop was left on surface, and direct-
drill is available then No-Till is suitable. Please enter more data." ) );

     /*************************************
      **** RULE: StrawRemoved
      *************************************/
MakeRule( StrawRemoved, [x|NewZealand],
   x:Harvesting #= Removed,
   PostMessage( "If straw residue from previous crop was removed, and direct drill is
available, and seed micro-environment is moist, No-Till is suitable. Please enter more
data." ) );
```

```
/*************************************
 **** RULE: MoistureDry
 *************************************/
MakeRule( MoistureDry, [x|NewZealand],
   x:Moisture #= Dry,
   PostMessage( "If the soil around seed micro-environment is dry, and no suitable direct-drill is available for seeding, then conventional tillage suits. Please enter more data." ) );

/*************************************
 **** RULE: MoistureMoist
 *************************************/
MakeRule( MoistureMoist, [x|NewZealand],
   x:Moisture #= Moist,
   PostMessage( "If the soil around seed micro-environment is moist or wetter, and a suitable direct-drill is also available for seeding, then No-Till suits.  Please enter more data." ) );

/*************************************
 **** RULE: SlopeMedium
 *************************************/
MakeRule( SlopeMedium, [x|NewZealand],
   x:Slope #= "Medium(5-12%)",
   PostMessage( "If slope is medium, meaning 5 to 12%, and a direct-drill is also available, No-Till are more suitable. However, more data is needed for a better recommendation." ) );

/*************************************
 **** RULE: SlopeHigh
 *************************************/
MakeRule( SlopeHigh, [x|NewZealand],
   x:Slope #= "High(>12%)",
   PostMessage( "If slope is high, meaning more than 12%, and a direct-drill is also available, and tractor can negotiate slopes, then No-Till is suitable. More data are needed for a better recommendation." ) );

/*************************************
 **** RULE: SlopeLow
 *************************************/
MakeRule( SlopeLow, [x|NewZealand],
   x:Slope #= "Low(<5%)",
   PostMessage( "If field is flat, or slope is low (upto 5% and less), and direct-drill is also available, No-Till or Conventional-Tillage both are suitable. However, more data are needed for a better recommendation." ) );

/*************************************
 **** RULE: TTGood
 *************************************/
```

```
MakeRule( TTGood, [x|NewZealand],
   x:TTransfer #= Excellent Or x:TTransfer #= Good,
   PostMessage( "If local agricultural extension services are good in providing
information w.r.t. using appropriate pesticides, herbicides etc., then No-Till suits. More
data is needed for a better recommendation." ) );

     /*************************************
      **** RULE: DrillAvail
      *************************************/
MakeRule( DrillAvail, [x|NewZealand],
   x:Drill #= Available,
   PostMessage( "If farmer has access to a direct drill which can work in local
conditions, and can penetrate into straw residue (if left), No-Till suits. Please enter more
data." ) );

     /*************************************
      **** RULE: DrillNotAvail
      *************************************/
MakeRule( DrillNotAvail, [x|NewZealand],
   x:Drill #= "Not Available",
   PostMessage( "If farmer has not any access to a direct drill, conventional tillage
methods suit. However, please enter more data for a better recommendation." ) );

     /*************************************
      **** RULE: ChemicalsAvail
      *************************************/
MakeRule( ChemicalsAvail, [x|NewZealand],
   x:Chemicals #= Available,
   PostMessage( "If appropriate pesticides and herbicides are available, and all other
factors also favour, No-Till suits. Please enter more data for a better recommendation."
) );

     /*************************************
      **** RULE: ChemicalsNotAvail
      *************************************/
MakeRule( ChemicalsNotAvail, [x|NewZealand],
   x:Chemicals #= "Not Available",
   PostMessage( "If appropriate pesticides and herbicides are not available conventional
tillage methods suit. Please enter more data for a better recommendation." );

     /*************************************
      **** RULE: TractorSmall
      *************************************/
MakeRule( TractorSmall, [x|NewZealand],
   x:Tractor #= "Range 45-70HP",
   PostMessage( "Farmers having tractors 45-70HP range, are generally those who have
low land holdings capacity. These are the farmers who need to adopt No-Till." ) );
```

```
/************************************
 **** RULE: TractorLarge
 ************************************/
MakeRule( TractorLarge, [x|NewZealand],
   x:Tractor #= "More than 70HP",
   PostMessage( "Farmers with bigger tractors may also have other range of agricultural
equipment for their large land holdings. No-Till or Conventional methods both can be
suitable depending upon other factors." ) );

/************************************
 **** RULE: GrowCom1
 ************************************/
MakeRule( GrowCom1, [x|NewZealand],
   x:GrowCom #= Yes,
   Execute( "C:\kappa\nzrocom.doc" ) );

/************************************
 **** RULE: GrowCom2
 ************************************/
MakeRule( GrowCom2, [x|NewZealand],
   x:GrowCom #= No,
   ShowWindow( Comments ) );

/************************************
 **** RULE: SoilCom1
 ************************************/
MakeRule( SoilCom1, [x|NewZealand],
   x:SoilCom #= Yes,
   Execute( "C:\kappa\nzsocom.doc" ) );

/************************************
 **** RULE: SoilCom2
 ************************************/
MakeRule( SoilCom2, [x|NewZealand],
   x:SoilCom #= No,
   ShowWindow( Comments ) );

/************************************
 **** RULE: MoistureCom1
 ************************************/
MakeRule( MoistureCom1, [x|NewZealand],
   x:MoistureCom #= Yes,
   Execute( "C:\kappa\nzmocom.doc" ) );

/************************************
 **** RULE: MoistureCom2
 ************************************/
MakeRule( MoistureCom2, [x|NewZealand],
```

```
   x:MoistureCom #= No,
   ShowWindow( Comments ) );

     /************************************
     **** RULE: HarvestingCom1
     ************************************/
MakeRule( HarvestingCom1, [x|NewZealand],
   x:HarvestingCom #= Yes,
   Execute( "C:\kappa\nzharcom.doc" ) );

     /************************************
     **** RULE: HarvestingCom2
     ************************************/
MakeRule( HarvestingCom2, [x|NewZealand],
   x:HarvestingCom #= No,
   ShowWindow( Comments ) );

     /************************************
     **** RULE: SlopeCom1
     ************************************/
MakeRule( SlopeCom1, [x|NewZealand],
   x:SlopeCom #= Yes,
   Execute( "C:\kappa\nzslpcom.doc" ) );

     /************************************
     **** RULE: SlopeCom2
     ************************************/
MakeRule( SlopeCom2, [x|NewZealand],
   x:SlopeCom #= No,
   ShowWindow( Comments ) );

     /************************************
     **** RULE: ChemicalsCom1
     ************************************/
MakeRule( ChemicalsCom1, [x|NewZealand],
   x:ChemicalsCom #= Yes,
   Execute( "C:\kappa\nzchcom.doc" ) );

     /************************************
     **** RULE: ChemicalsCom2
     ************************************/
MakeRule( ChemicalsCom2, [x|NewZealand],
   x:ChemicalsCom #= No,
   ShowWindow( Comments ) );

     /************************************
     **** RULE: TTCom1
     ************************************/
```

```
MakeRule( TTCom1, [x|NewZealand],
   x:TTCom #= Yes,
   Execute( "C:\kappa\nzttcom.doc" ) );

     /**********************************
      **** RULE: TTCom2
      **********************************/
MakeRule( TTCom2, [x|NewZealand],
   x:TTCom #= No,
   ShowWindow( Comments ) );

     /**********************************
      **** RULE: TractorCom1
      **********************************/
MakeRule( TractorCom1, [x|NewZealand],
   x:TractorCom #= Yes,
   Execute( "C:\kappa\nztrcom.doc" ) );

     /**********************************
      **** RULE: TractorCom2
      **********************************/
MakeRule( TractorCom2, [x|NewZealand],
   x:TractorCom #= No,
   ShowWindow( Comments ) );

     /**********************************
      **** RULE: DrillCom1
      **********************************/
MakeRule( DrillCom1, [x|NewZealand],
   x:DrillCom #= Yes,
   Execute( "C:\kappa\nzdrcom.doc" ) );

     /**********************************
      **** RULE: DrillCom2
      **********************************/
MakeRule( DrillCom2, [x|NewZealand],
   x:DrillCom #= No,
   ShowWindow( Comments ) );

     /**********************************
      **** RULE: PastureCereal
      **********************************/
MakeRule( PastureCereal, [x|NewZealand],
   ( x:Harvested #= Pasture ) And ( x:Grow #= "Any cereals" ),
   PostMessage( "When converting pasture to cereals production, it is recommended to
sow an intermediate crop such as fodder to avoid pest transfer. However,  more data are
required to get a better recommendation." ) );
```

```
   /************************************
    **** RULE: PasturePasture
    ************************************/
MakeRule( PasturePasture, [x|NewZealand],
   ( x:Harvested #= Pasture ) And ( x:Grow #= Pasture ),
   PostMessage( "Pasture renewal is commonly practiced in New Zealand by over-
drilling. However, more data are required for a better recommendation." ) );

   /************************************
    **** RULE: TTBad
    ************************************/
MakeRule( TTBad, [x|NewZealand],
   x:TTransfer #= Bad,
   PostMessage( "If  extension services are not well aware of  information on using
appropriate pesticides, herbicides etc., then conventional tillage suits. More data is
needed for a better recommendation." ) );

   /************************************
    **** RULE: HarvestedCereal
    ************************************/
MakeRule( HarvestedCereal, [x|NewZealand],
   x:Harvested #= "Any cereals",
   PostMessage( "Information provided is not enough. Please enter more data. Thanks."
) );

   /************************************
    **** RULE: HarvestedPasture
    ************************************/
MakeRule( HarvestedPasture, [x|NewZealand],
   x:Harvested #= Pasture,
   PostMessage( "Information provided is not enough. Please enter more data. Thanks."
) );

   /************************************
    **** RULE: GrowPasture
    ************************************/
MakeRule( GrowPasture, [x|NewZealand],
   x:Grow #= Pasture,
   PostMessage( "Information provided is not enough. Please enter more data. Thanks."
) );

   /************************************
    **** RULE: GrowCereal
    ************************************/
MakeRule( GrowCereal, [x|NewZealand],
   x:Grow #= "Any cereals",
   PostMessage( "Information provided is not enough. Please enter more data. Thanks."
) );
```

```
    /************************************
     **** RULE: StoneMed
     ************************************/
MakeRule( StoneMed, [x|Drills],
   x:DrillTypes #= "Stone (medium) texture",
   PostMessage( "Light drills with spring tine legs and limited depth control winged or
hoe openers are suitable under such conditions" ) );
    /************************************
     **** RULE: StoneLar
     ************************************/
MakeRule( StoneLar, [x|Drills],
   x:DrillTypes #= "Stone (large) texture",
   PostMessage( "Heavy duty direct drills with parallel floating drag arms having winged
or hoe openers are suitable under such conditions" ) );

    /************************************
     **** RULE: StandStubble
     ************************************/
MakeRule( StandStubble, [x|Drills],
   x:DrillTypes #= "Standing stubble",
   PostMessage( "Light or heavy duty direct drill with parallel floating drag arms having
winged or hoe openers are suitable under such conditions" ) );

    /************************************
     **** RULE: LyingResidue
     ************************************/
MakeRule( LyingResidue, [x|Drills],
   x:DrillTypes #= "Lying residue",
   PostMessage( "Conventional drills with floating drag arms, or any heavy duty direct
drill with floating drag arms are suitable under such conditions" ) );

    /************************************
     **** RULE: BareSoil
     ************************************/
MakeRule( BareSoil, [x|Drills],
   x:DrillTypes #= "Bare soil, short pasture",
   PostMessage( "Light or heavy duty drills with spring tine legs, or floating drag arms,
and limited depth control, having winged or hoe openers are suitable under such
conditions" ) );

    /************************************
     **** RULE: ConvenTill
     ************************************/
MakeRule( ConvenTill, [x|Drills],
   x:DrillTypes #= "Conventional-Tillage",
   ShowWindow( SESSION ) );
```

Rules from File: PKC.kal

```
/************************************
     ****  RULE: Rule2
     *************************************/
MakeRule( Rule2, [x|Pakistan],
  ( x:Grow #= Rice Or x:Grow #= Cotton ) And ( x:Harvested #=
                                      Wheat )
     And ( x:Soil #= Clayey ) And ( x:Drill #= "Not Available" )
     And ( x:Chemicals #= "Not Available" ) And ( x:Harvesting
                                       #= Removed )
     And ( x:Moisture #= Dry ) And ( x:TTransfer #= Bad )
     And ( x:Tractor #= "More than 70HP" ) And ( x:Slope #= "Low(<5%)" ),
  PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques. For further details please press button  <Please
explain> and read appropriate explanation. [2]" ) );

    /************************************
     ****  RULE: Rule4
     *************************************/
MakeRule( Rule4, [x|Pakistan],
  (x:Harvested #= Cotton And x:Grow #= Cotton)( x:Harvested
                                       #= Cotton
                                       And x:Grow
                                       #= Rice )
    Or ((((x:Harvested #= Rice And x:Grow #= Cotton)(
          x:Harvested #= Rice And x:Grow #= Rice ))( x:Harvested
                                               #=
                                               Wheat
                                               And
                                               x:Grow
                                               #=
                                               Wheat ))( x:Harvested
                                                        #=
                                                        Wheat
                                                        And
                                                        x:Grow
                                                        #=
                                                        Rice ))( x:Harvested
                                                               #=
                                                               Wheat
                                                               And
                                                               x:Grow
                                                               #=
                                                               Cotton )
    Or ( x:Grow #= Cotton ) Or ( x:Grow #= Rice )
     Or ( x:Harvested #= Wheat ) Or ( x:Soil #= Clayey )
     Or ( x:Chemicals #= "Not Available" ) Or ( x:Drill #= "Not Available" ),
```

```
   PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques. For further details please press button <Please
explain> and read appropriate explanation. [4]" ) );

     /************************************
      **** RULE: Rule3
      ************************************/
MakeRule( Rule3, [x|Pakistan],
   ( x:Harvested #= Rice And x:Grow #= Wheat ) Or ( x:Harvested
                                          #= Cotton
                                          And x:Grow
                                          #= Wheat )
      Or ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
      Or ( x:Drill #= Available ) Or ( x:Chemicals #= Available )
      Or ( x:Harvesting #= "Left on surface" ) Or ( x:TTransfer
                                          #= Excellent
                                          Or x:TTransfer
                                          #= Good )
      Or ( x:Tractor #= "Range 45-70HP" ) Or ( x:Slope #= "Medium(5-12%)"
                                     Or x:Slope
                                     #= "High(>12%)" ),
   PostMessage( "Under the selected conditions No-Till suits. For further details please
press button <Please explain> and read appropriate explanation. [3]" ) );

     /************************************
      **** RULE: Rule1
      ************************************/
MakeRule( Rule1, [x|Pakistan],
   ( x:Grow #= Wheat ) And ( x:Harvested #= Rice Or x:Harvested
                      #= Cotton ) And ( x:Soil #=
                                          Sandy
                                          Or x:Soil
                                          #= "Silt Loam" )
      And ( x:Drill #= Available ) And ( x:Chemicals #= Available )
      And ( x:Harvesting #= "Left on surface" ) And ( x:Moisture
                                          #= Moist )
      And ( x:TTransfer #= Excellent Or x:TTransfer #= Good )
      And ( x:Tractor #= "Range 45-70HP" ) And ( x:Slope #= "Medium(5-12%)"
                                        Or x:Slope
                                        #= "High(>12%)" ),
   PostMessage( "Under the selected conditions No-Till suits. For further details please
press button <Please explain> and read appropriate explanation. [1]" ) );

     /************************************
      **** RULE: SoilCons
      ************************************/
MakeRule( SoilCons, [x|Pakistan],
   x:Tillage #= "No-Till",
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```
  x:Soil = "SandyLoam Or SiltLoam";
 PostMessage( "The soil texture should to be either  ", x:Soil );
 } );

   /************************************
    **** RULE: SoilConv
    ************************************/
MakeRule( SoilConv, [x|Pakistan],
 x:Tillage #= "Conventional-Tillage",
 {
 x:Soil = Clayey;
 PostMessage( "The soil texture seems to be  ", x:Soil );
 } );

   /************************************
    **** RULE: GrowCons
    ************************************/
MakeRule( GrowCons, [x|Pakistan],
 x:Tillage #= "No-Till",
 {
 x:Grow = Wheat;
 PostMessage( "The  crop to be grown should be  ", x:Grow );
 } );

   /************************************
    **** RULE: GrowConv
    ************************************/
MakeRule( GrowConv, [x|Pakistan],
 x:Tillage #= "Conventional-Tillage",
 {
 x:Grow = "Rice Or Cotton";
 PostMessage( "The next crop grown should either be  ", x:Grow );
 } );

   /************************************
    **** RULE: DrillCons
    ************************************/
MakeRule( DrillCons, [x|Pakistan],
 x:Tillage #= "No-Till",
 {
 x:Drill = Available;
 PostMessage( "The No-Till  drill should be  ", x:Drill );
 } );

   /************************************
    **** RULE: DrillConv
    ************************************/
MakeRule( DrillConv, [x|Pakistan],
```

```
  x:Tillage #= "Conventional-Tillage",
  {
  x:Drill = "Not available";
  PostMessage( "The No-Till  drill seems to be  ", x:Drill );
  } );

    /*************************************
     ****  RULE: TractorCons
     *************************************/
MakeRule( TractorCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Tractor = "Range 45-70HP";
  PostMessage( "Tractor power available should  ", x:Tractor );
  } );

    /*************************************
     ****  RULE: TractorConv
     *************************************/
MakeRule( TractorConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Tractor = "More than 70HP";
  PostMessage( "Tractor available power seems to be ", x:Tractor );
  } );

    /*************************************
     ****  RULE: TTransferCons
     *************************************/
MakeRule( TTransferCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:TTransfer = "Excellent Or Good";
  PostMessage( "The level of extension facilities should be either ",
     x:TTransfer );
  } );

    /*************************************
     ****  RULE: TTransferConv
     *************************************/
•MakeRule( TTransferConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:TTransfer = Bad;
  PostMessage( "The level of extension facilities available is rated as  ",
     x:TTransfer );
  } );
```

```
    /************************************
     **** RULE: ChemicalsCons
     ************************************/
MakeRule( ChemicalsCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Chemicals = Available;
   PostMessage( "The herbicides chemical should be  ", x:Chemicals );
   } );

    /************************************
     **** RULE: ChemicalsConv
     ************************************/
MakeRule( ChemicalsConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Chemicals = "Not  available";
   PostMessage( "The required herbicides chemicals seem  to be ",
      x:Chemicals );
   } );

    /************************************
     **** RULE: HarvestingCons
     ************************************/
MakeRule( HarvestingCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Harvesting = "Left on surface";
   PostMessage( "The previous crop residue should be  ", x:Harvesting );
   } );

    /************************************
     **** RULE: HarvestingConv
     ************************************/
MakeRule( HarvestingConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Harvesting = Removed;
   PostMessage( "From  previous crop residue should have been  ",
      x:Harvesting );
   } );

    /************************************
     **** RULE: MoistureCons
     ************************************/
MakeRule( MoistureCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
```

```
  x:Moisture = Moist;
  PostMessage( "The soil moisture at the time of planting should be  ",
     x:Moisture );
  } );

    /************************************
     **** RULE: MoistureConv
     ************************************/
MakeRule( MoistureConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Moisture = Dry;
  PostMessage( "The soil moisture at time of planting should be  ",
     x:Moisture );
  } );

    /************************************
     **** RULE: HarvestedCons
     ************************************/
MakeRule( HarvestedCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Harvested = "Rice Or Cotton";
  PostMessage( "The harvested crop should  either be  ", x:Harvested );
  } );

    /************************************
     **** RULE: HarvestedConv
     ************************************/
MakeRule( HarvestedConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvested = Wheat;
  PostMessage( "The harvested crop seems to be ", x:Harvested );
  } );

   /************************************
     **** RULE: SlopeCons
     ************************************/
MakeRule( SlopeCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Slope = "Medium(5-10%) Or High(>10%)";
  PostMessage( "The slope of  the field should be ", x:Slope );
  } );
```

```
/************************************
 **** RULE: SlopeConv
 *************************************/
MakeRule( SlopeConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Slope = "flat, (lower than 5% and direct-drill seems not available";
   PostMessage( "Slope of  the field  seems to be ", x:Slope );
   } );

/************************************
 **** RULE: HarvestedCoRicWheat
 *************************************/
MakeRule( HarvestedCoRicWheat, [x|Pakistan],
   ( x:Harvested #= Cotton ) Or ( x:Harvested #= Rice )
      Or ( x:Harvested #= Wheat ),
   PostMessage( "Information provided is not enough. Please enter more data." ) );

/************************************
 **** RULE: GrowCoRicWheat
 *************************************/
MakeRule( GrowCoRicWheat, [x|Pakistan],
   ( x:Grow #= Cotton ) Or ( x:Grow #= Rice ) Or ( x:Grow #=
                                             Wheat ),
   PostMessage( "Information provided is not enough. Please enter more data." ) );

/************************************
 **** RULE: SoilLoam
 *************************************/
MakeRule( SoilLoam, [x|Pakistan],
   x:Soil #= Sandy Or x:Soil #= "Silt Loam",
   PostMessage( "Sandy to Sandy Loam and Silt Loam soils are suited to No-Till.
Generally, all well drained soils are also suitable for No-Till cropping. Please enter more
data." ) );
/************************************
 **** RULE: MoistureMoist
 *************************************/
MakeRule( MoistureMoist, [x|Pakistan],
   x:Moisture #= Moist,
   PostMessage( "If the soil around seed micro-environment is moist or wetter, and a
suitable direct-drill is also available for seeding, then No-Till suits. Please enter more
data." ) );

/************************************
 **** RULE: StrawRemoved
 *************************************/
•MakeRule( StrawRemoved, [x|Pakistan],
   x:Harvesting #= Removed,
```

PostMessage("If straw residue from previous crop was removed, direct-drill is available, and seed micro--environment is moist or wetter, No-Till suits. Please enter more data."));

```
/************************************
 **** RULE: MoistureDry
 ************************************/
MakeRule( MoistureDry, [x|Pakistan],
   x:Moisture #= Dry,
   PostMessage( "If the soil around seed micro-environment is dry, and no suitable No-Till drill is available for seeding, then conventional tillage suits. Please enter more data." ) );

/************************************
 **** RULE: SlopeMedium
 ************************************/
MakeRule( SlopeMedium, [x|Pakistan],
   x:Slope #= "Medium(5-12%)",
   PostMessage( "If slope is medium, meaning 5 to 12%, and a direct-drill is also available, No-Till is more suitable. Please enter more data." ) );

/************************************
 **** RULE: TTGood
 ************************************/
•MakeRule( TTGood, [x|Pakistan],
   x:TTransfer #= Excellent Or x:TTransfer #= Good,
   PostMessage( "If the local agricultural extension is providing good information w.r.t. No-Till (for pesticide, herbicide application etc.), then No-Till suits. Please enter more data." ) );

/************************************
 **** RULE: TTBad
 ************************************/
MakeRule( TTBad, [x|Pakistan],
   x:TTransfer #= Bad,
   PostMessage( "If the local agricultural extension is not well aware with information w.r.t. No-Till (for pesticide, herbicide application etc.), then conventional tillage suits. Please enter more data." ) );

/************************************
 **** RULE: DrillAvail
 ************************************/
MakeRule( DrillAvail, [x|Pakistan],
   x:Drill #= Available,
   PostMessage( "If farmer has access to a direct-drill which can work in local conditions, and can penetrate into straw residue (if left), No-Till suits. Please enter more data." ) );
```

```
/************************************
 **** RULE: DrillNotAvail
 *************************************/
MakeRule( DrillNotAvail, [x|Pakistan],
   x:Drill #= "Not Available",
   PostMessage( "If farmer has not any access to a direct-drill, conventional tillage
method should continue in such field. Please enter more data." ) );

/************************************
 **** RULE: PesticidesAvail
 *************************************/
MakeRule( PesticidesAvail, [x|Pakistan],
   x:Chemicals #= Available,
   PostMessage( "If appropriate pesticides and herbicides are available, and all other
factors also favour, No-Till suits. Please enter more data." ) );

/************************************
 **** RULE: PesticidesNotAvail
 *************************************/
MakeRule( PesticidesNotAvail, [x|Pakistan],
   x:Chemicals #= "Not Available",
   PostMessage( "If appropriate pesticides and herbicides are not available, conventional
tillage methods suits. Please enter more data." ) );

/************************************
 **** RULE: TractorSmall
 *************************************/
MakeRule( TractorSmall, [x|Pakistan],
   x:Tractor #= "Range 45-70HP",
   PostMessage( "Farmers having tractors 45-70HP range are generally have low land
holding capacity. These are the farmers who need to adopt No-Till. Please enter more
data." ) );

/************************************
 **** RULE: TractorLarge
 *************************************/
MakeRule( TractorLarge, [x|Pakistan],
   x:Tractor #= "More than 70HP",
   PostMessage( "Farmers with bigger tractors may also have other range of agricultural
equipment. No-Till or conventional method, either can suit, depending upon other
factors. Please enter more data." ) );

/************************************
 **** RULE: GrowCom1
 *************************************/
MakeRule( GrowCom1, [x|Pakistan],
   x:GrowCom #= Yes,
   Execute( "C:\kappa\pkrotcom.doc" ) );
```

```
/************************************
 **** RULE: GrowCom2
 ************************************/
MakeRule( GrowCom2, [x|Pakistan],
  x:GrowCom #= No,
  ShowWindow( Comments ) );

/************************************
 **** RULE: SoilCom1
 ************************************/
MakeRule( SoilCom1, [x|Pakistan],
  x:SoilCom #= Yes,
  Execute( "C:\kappa\pksocom.doc" ) );

/************************************
 **** RULE: SoilCom2
 ************************************/
MakeRule( SoilCom2, [x|Pakistan],
  x:SoilCom #= No,
  ShowWindow( Comments ) );

/************************************
 **** RULE: MoistureCom1
 ************************************/
MakeRule( MoistureCom1, [x|Pakistan],
  x:MoistureCom #= Yes,
  Execute( "C:\kappa\pkmocom.doc" ) );

/************************************
 **** RULE: MoistureCom2
 ************************************/
MakeRule( MoistureCom2, [x|Pakistan],
  x:MoistureCom #= No,
  ShowWindow( Comments ) );

/************************************
 **** RULE: HarvestingCom1
 ************************************/
MakeRule( HarvestingCom1, [x|Pakistan],
  x:HarvestingCom #= Yes,
  Execute( "C:\kappa\pkharcom.doc" ) );

/************************************
 **** RULE: HarvestingCom2
 ************************************/
MakeRule( HarvestingCom2, [x|Pakistan],
  x:HarvestingCom #= No,
  ShowWindow( Comments ) );
```

```
  /************************************
   **** RULE: SlopeCom1
   ************************************/
MakeRule( SlopeCom1, [x|Pakistan],
  x:SlopeCom #= Yes,
  Execute( "C:\kappa\pkslpcom.doc" ) );

  /************************************
   **** RULE: SlopeCom2
   ************************************/
MakeRule( SlopeCom2, [x|Pakistan],
  x:SlopeCom #= No,
  ShowWindow( Comments ) );

  /************************************
   **** RULE: ChemicalsCom1
   ************************************/
MakeRule( ChemicalsCom1, [x|Pakistan],
  x:ChemicalsCom #= Yes,
  Execute( "C:\kappa\pkchcom.doc" ) );

  /************************************
   **** RULE: ChemicalsCom2
   ************************************/
MakeRule( ChemicalsCom2, [x|Pakistan],
  x:ChemicalsCom #= No,
 ShowWindow( Comments ) );

  /************************************
   **** RULE: TTCom1
   ************************************/
MakeRule( TTCom1, [x|Pakistan],
  x:TTCom #= Yes,
  Execute( "C:\kappa\pkttcom.doc" ) );

  /************************************
   **** RULE: TTCom2
   ************************************/
MakeRule( TTCom2, [x|Pakistan],
  x:TTCom #= No,
  ShowWindow( Comments ) );

  /************************************
   **** RULE: TractorCom1
   ************************************/
MakeRule( TractorCom1, [x|Pakistan],
  x:TractorCom #= Yes,
  Execute( "C:\kappa\pktrcom.doc" ) );
```

```
/************************************
  **** RULE: TractorCom2
  *************************************/
MakeRule( TractorCom2, [x|Pakistan],
   x:TractorCom #= No,
   ShowWindow( Comments ) );

/************************************
  **** RULE: DrillCom1
  *************************************/
MakeRule( DrillCom1, [x|Pakistan],
   x:DrillCom #= Yes,
   Execute( "C:\kappa\pkdrcom.doc" ) );

/************************************
  **** RULE: DrillCom2
  *************************************/
MakeRule( DrillCom2, [x|Pakistan],
   x:DrillCom #= No,
   ShowWindow( Comments ) );

/************************************
  **** RULE: StrawLeft
  *************************************/
MakeRule( StrawLeft, [x|Pakistan],
   x:Harvesting #= "Left on surface",
   PostMessage( "If straw residue from previous crop was left on the surface, and
direct-drill is available then No-Till is suitable. Please enter more data." ) );

/************************************
  **** RULE: SoilClayey
  *************************************/
MakeRule( SoilClayey, [x|Pakistan],
   x:Soil #= Clayey,
   PostMessage( "Undrained clayey soils are not suitable for adoption of No-Till.
However, if drained, could be suitable for No-Till. Please enter more data." ) );

/************************************
  **** RULE: SlopeHigh
  *************************************/
MakeRule( SlopeHigh, [x|Pakistan],
   x:Slope #= "High(>12%)",
   PostMessage( "If slope is high, meaning more than 12%, and a direct-drill is also
available, and tractor can negotiate slopes, then No-Till is most suitable. Please enter
more data." ) );
```

```
/************************************
 **** RULE: SlopeLow
 ************************************/
MakeRule( SlopeLow, [x|Pakistan],
  x:Slope #= "Low(<5%)",
  PostMessage( "If field is flat, or slope is low, meaning less than 5%, and a direct-drill
is also available, No-Till or conventional methods both are suitable. Please enter more
data." ) );

/************************************
 **** RULE: StoneMed
 ************************************/
MakeRule( StoneMed, [x|Drills],
  x:DrillTypes #= "Stone (medium) texture",
  PostMessage( "Light drills with spring tine legs and limited depth control winged or
hoe openers are suitable under such conditions" ) );

/************************************
 **** RULE: StoneLar
 ************************************/
MakeRule( StoneLar, [x|Drills],
  x:DrillTypes #= "Stone (large) texture",
  PostMessage( "Heavy duty direct drills with parallel floating drag arms having winged
openers are suitable under such conditions" ) );

/************************************
 **** RULE: StandStubble
 ************************************/
MakeRule( StandStubble, [x|Drills],
  x:DrillTypes #= "Standing stubble",
  PostMessage( "Light or heavy duty direct drill with parallel floating drag arms having
winged or hoe openers are suitable under such conditions" ) );

/************************************
 **** RULE: LyingResidue
 ************************************/
MakeRule( LyingResidue, [x|Drills],
  x:DrillTypes #= "Lying residue",
  PostMessage( "Conventional drills with floating drag arms, or any heavy duty direct
drill with floating drag arms are suitable under such conditions" ) );

/************************************
 **** RULE: BareSoil
 ************************************/
MakeRule( BareSoil, [x|Drills],
  x:DrillTypes #= "Bare soil, short pasture",
```

```
   PostMessage( "Light or heavy duty drills with spring tine legs, or floating drag arms,
and limited depth control, having winged or hoe openers are suitable under such
conditions" ) );

     /*************************************
      **** RULE: ConvenTill
      *************************************/
MakeRule( ConvenTill, [x|Drills],
   x:DrillTypes #= "Conventional-Tillage",
   ShowWindow( SESSION ) );
```

Rules from File: PKR.kal

```
/*************************************
      **** RULE: Rule2
      *************************************/
MakeRule( Rule2, [x|Pakistan],
   ( x:Grow #= Rice Or x:Grow #= Cotton ) And ( x:Harvested #=
                                        Wheat )
      And ( x:Variety #= "Late maturing" ) And ( x:Soil #= Clayey )
      And ( x:Drill #= "Not Available" ) And ( x:Chemicals #=
                                        "Not Available" )
      And ( x:RSB #= Yes ) And ( x:Pesticides #= "Not Available" )
      And ( x:Harvesting #= Removed ) And ( x:Moisture #= Dry )
      And ( x:TTransfer #= Bad ) And ( x:Tractor #= "More than 70HP" )
      And ( x:Slope #= "Low(<5%)" ),
   PostMessage( "The given conditions suggest that farmer should continue with
conventional tillage techniques. For further details please press button <Please explain>
and read appropriate explanation." ) );

     /*************************************
      **** RULE: Rule4
      *************************************/
MakeRule( Rule4, [x|Pakistan],
   (x:Harvested #= Cotton And x:Grow #= Cotton)( x:Harvested
                                        #= Cotton
                                        And x:Grow
                                        #= Rice )
      Or ((((x:Harvested #= Rice And x:Grow #= Cotton)(
            x:Harvested #= Rice And x:Grow #= Rice ))( x:Harvested
                                                #=
                                                Wheat
                                                And
                                                x:Grow
                                                #=
                                                Cotton ))( x:Harvested
                                                           #=
                                                           Wheat
                                                           And
```

```
                                                  x:Grow
                                                  #=
                                                  Rice ))( x:Harvested
                                                           #=
                                                           Wheat
                                                           And
                                                           x:Grow
                                                           #=
                                                           Cotton )
    Or ( x:Grow #= Cotton ) Or ( x:Grow #= Rice )
    Or ( x:Harvested #= Wheat ) Or ( x:Chemicals #= "Not Available" )
    Or ( x:Drill #= "Not Available" ) Or ( x:Soil #= Clayey )
    Or ( x:Pesticides #= "Not Available" ),
  PostMessage( "The given conditions suggest that farmer should continue with
conventional tillage techniques. For further details please press button <Please explain>
and read appropriate explanation." ) );

    /************************************
    **** RULE: Rule3
    ************************************/
MakeRule( Rule3, [x|Pakistan],
  ( x:Harvested #= Cotton And x:Grow #= Wheat ) Or ( x:Harvested
                                        #=
                                        Rice
                                        And
                                        x:Grow
                                        #=
                                        Wheat )
    Or ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
    Or ( x:Drill #= Available ) Or ( x:Chemicals #= Available )
    Xor ( x:Harvesting #= "Left on surface" ) Or ( x:RSB #=
                                       No )
    Or ( x:RSB #= Yes And x:Pesticides #= Available )
    Or ( x:TTransfer #= Excellent Or x:TTransfer #= Good )
    Or ( x:Tractor #= "Range 45-70HP" ) Or ( x:Slope #= "Medium(5-12%)"
                                    Or x:Slope
                                    #= "High(>12%)" ),
  PostMessage( "Under selected conditions No-Till suits. For further details please
press button <Please explain> and read appropriate explanation." ) );

    /************************************
    **** RULE: Rule1
    ************************************/
MakeRule( Rule1, [x|Pakistan],
  ( x:Grow #= Wheat ) And ( x:Harvested #= Rice Or x:Harvested
                 #= Cotton ) And ( x:Variety
                                   #= "Early maturing"
                                   Or x:Variety
```

```
                                    #= "Mid maturing" )
      And ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
      And ( x:Drill #= Available ) And ( x:Chemicals #= Available )
      And ( x:RSB #= No ) And ( x:RSB #= Yes And x:Pesticides
                              #= Available )
      And ( x:Pesticides #= Available ) And ( x:Harvesting #=
                                          "Left on surface" )
      And ( x:Moisture #= Moist ) And ( x:TTransfer #= Excellent
                                      Or x:TTransfer #=
                                      Good )
      And ( x:Tractor #= "Range 45-70HP" ) And ( x:Slope #= "Medium(5-12%)"
                                           Or x:Slope
                                          #= "High(>12%)" ),
   PostMessage( "Under selected conditions No-Tillage suits. For further details please
press button <Please explain> and read appropriate explanation." ) );

     /*************************************
      ****  RULE: SoilCons
      *************************************/
MakeRule( SoilCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Soil = "Sandy Or Silt Loam";
   PostMessage( "The soil texture should to be either  ", x:Soil );
  } );

     /*************************************
      ****  RULE: SoilConv
      *************************************/
MakeRule( SoilConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Soil = Clayey;
   PostMessage( "The soil texture seems to be  ", x:Soil );
   } );
     /*************************************
      ****  RULE: GrowCons
      *************************************/
MakeRule( GrowCons, [x|Pakistan],
  x:Tillage #= "No-Till",
   {
   x:Grow = Wheat;
   PostMessage( "The  crop to be grown should be  ", x:Grow );
   } );

     /*************************************
      ****  RULE: GrowConv
      *************************************/
```

```
MakeRule( GrowConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Grow = "Rice Or Cotton";
   PostMessage( "The next crop grown should either be  ", x:Grow );
   } );

     /*************************************
     **** RULE: DrillCons
      *************************************/
MakeRule( DrillCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Drill = Available;
   PostMessage( "The No-Till  drill should be  ", x:Drill );
   } );

     /*************************************
      **** RULE: DrillConv
      *************************************/
MakeRule( DrillConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Drill = "Not available";
   PostMessage( "The No-Till  drill seems to be  ", x:Drill );
   } );

     /*************************************
      **** RULE: TractorCons
      *************************************/
MakeRule( TractorCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Tractor = "Range 45-70HP";
   PostMessage( "Tractor power available should  ", x:Tractor );
   } );

     /*************************************
      **** RULE: TractorConv
      *************************************/
MakeRule( TractorConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Tractor = "More than 70HP";
   PostMessage( "Tractor available power seems to be ", x:Tractor );
   } );
```

```
    /************************************
     **** RULE: TTransferCons
     ************************************/
MakeRule( TTransferCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:TTransfer = "Excellent Or Good";
   PostMessage( "The level of extension facilities should be either ",
      x:TTransfer );
   } );

    /************************************
     **** RULE: TTransferConv
     ************************************/
MakeRule( TTransferConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
  {
  x:TTransfer = Bad;
   PostMessage( "The level of extension facilities available is rated as  ",
      x:TTransfer );
   } );

    /************************************
     **** RULE: ChemicalsCons
     ************************************/
MakeRule( ChemicalsCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Chemicals = Available;
   PostMessage( "The herbicides chemical should be   ", x:Chemicals );
   } );

    /************************************
     **** RULE: ChemicalsConv
     ************************************/
MakeRule( ChemicalsConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Chemicals = "Not  available";
   PostMessage( "The required herbicides chemicals seem  to be ",
      x:Chemicals );
   } );

    /************************************
     **** RULE: HarvestingCons
     ************************************/
MakeRule( HarvestingCons, [x|Pakistan],
   x:Tillage #= "No-Till",
```

```
    x:Harvesting = "Left on surface";
  PostMessage( "The previous crop residue should be  ", x:Harvesting );
  } );

    /************************************
     **** RULE: HarvestingConv
     *************************************/
MakeRule( HarvestingConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvesting = Removed;
  PostMessage( "From  previous crop residue should have been  ",
     x:Harvesting );
  } );

    /************************************
     **** RULE: MoistureCons
     *************************************/
MakeRule( MoistureCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Moisture = Moist;
  PostMessage( "The soil moisture at the time of planting should be  ",
     x:Moisture );
  } );

    /************************************
     **** RULE: MoistureConv
     *************************************/
MakeRule( MoistureConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Moisture = Dry;
  PostMessage( "The soil moisture at time of planting should be  ",
     x:Moisture );
  } );

    /************************************
     **** RULE: HarvestedCons
     *************************************/
MakeRule( HarvestedCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Harvested = "Rice Or Cotton";
  PostMessage( "The harvested crop should  either be  ", x:Harvested );
  } );
```

```
/************************************
 **** RULE: HarvestedConv
 ************************************/
MakeRule( HarvestedConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Harvested = Wheat;
   PostMessage( "The harvested crop seems to be ", x:Harvested );
   } );

/************************************
 **** RULE: SlopeCons
 ************************************/
MakeRule( SlopeCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Slope = "Medium(5-12%) Or High(>12%)";
   PostMessage( "The slope of  the field should be ", x:Slope );
   } );

/************************************
 **** RULE: SlopeConv
 ************************************/
MakeRule( SlopeConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Slope = "Low(<5%)";
   PostMessage( "Slope of  the field  seems to be ", x:Slope );
   } );

/************************************
 **** RULE: VarietyEarly
 ************************************/
MakeRule( VarietyEarly, [x|Pakistan],
   x:Variety #= "Early maturing" Or x:Variety #= "Mid maturing",
   PostMessage( "To overcome the delay in planting of wheat after Rice and Cotton,
No-Till is encouraged. Thus depending on other variables, both No-Till or conventional
methods can be considered." ) );

/************************************
 **** RULE: TractorSmall
 ************************************/
MakeRule( TractorSmall, [x|Pakistan],
   x:Tractor #= "Range 45-70HP",
   PostMessage( "Farmers having tractors 45-70HP range are generally have low land
holding capacity. These are the farmers who need to adopt No-Till. Please enter more
data." ) );
```

```
/***********************************
 **** RULE: TractorLarge
 ***********************************/
MakeRule( TractorLarge, [x|Pakistan],
  x:Tractor #= "More than 70HP",
  PostMessage( "Farmers with bigger tractors may also have other range of agricultural
equipment. Depending upon other factors, No-Till, or conventional method, either can
be adopted. Please enter more data." ) );

/***********************************
 **** RULE: SoilClayey
 ***********************************/
MakeRule( SoilClayey, [x|Pakistan],
  x:Soil #= Clayey,
  PostMessage( "Undrained clayey soils are not suitable for adoption of No-Till.
However, if drained, could be suitable for No-Till. Please enter more data." ) );

/***********************************
 **** RULE: StrawLeft
 ***********************************/
MakeRule( StrawLeft, [x|Pakistan],
  x:Harvesting #= "Left on surface",
  PostMessage( "If straw residue from previous crop was left on the surface, and
direct-drill is also available which can penetrate into this straw for seed placement, then
No-Till suits. Please enter more data." ) );

/***********************************
 **** RULE: TTGood
 ***********************************/
MakeRule( TTGood, [x|Pakistan],
  x:TTransfer #= Excellent Or x:TTransfer #= Good,
  PostMessage( "If local agricultural extension is providing good information w.r.t. No-
Till (for pesticide, herbicide application etc.), then No-Till suits. Please enter more
data." ) );

/***********************************
 **** RULE: TTBad
 ***********************************/
MakeRule( TTBad, [x|Pakistan],
  x:TTransfer #= Bad,
  PostMessage( "If local agricultural extension is not well aware with information
w.r.t. No-Till (for pesticide, herbicide application etc.), then conventional tillage. Please
enter more data." ) );

/***********************************
 **** RULE: SlopeLow
 ***********************************/
MakeRule( SlopeLow, [x|Pakistan],
```

```
   x:Slope #= "Low(<5%)",
   PostMessage( "If field is flat and slope is less than 5%, and direct-drill is also
available, then No-Till or conventional methods both can be suitable, depending on other
factors. Please enter more data." ) );

     /*************************************
      **** RULE: MoistureMoist
      *************************************/
MakeRule( MoistureMoist, [x|Pakistan],
   x:Moisture #= Moist,
   PostMessage( "If the soil around seed micro-environment is moist, and a suitable
direct-drill is also available for seeding, then No-Till suits. Please enter more data ." ) );

     /*************************************
      **** RULE: RSBNo
      *************************************/
MakeRule( RSBNo, [x|Pakistan],
   x:RSB #= No,
   PostMessage( "If farm is not RSB affected then No-Till can be adopted. If it is within
RSB affected zone but requisite pesticides are available,  No-Till can be considered.
Please enter more data." ) );

     /*************************************
      **** RULE: RSBYes
      *************************************/
MakeRule( RSBYes, [x|Pakistan],
   x:RSB #= Yes,
   PostMessage( "In case farm is affected by RSB and requisite pesticides are not
available,  conventional tillage suits. However, if pesticides are available, No-Till can
also be considered. Please enter more data." ) );

     /*************************************
      **** RULE: ChemicalsAvail
      *************************************/
MakeRule( ChemicalsAvail, [x|Pakistan],
   x:Chemicals #= Available,
   PostMessage( "Chemicals play an important role in crops sown under No-Till
methods. Availability of requisite herbicide chemicals is essential for adopting No-Till.
Please enter more data." ) );

     /*************************************
      **** RULE: ChemicalsNotAvail
      *************************************/
MakeRule( ChemicalsNotAvail, [x|Pakistan],
   x:Chemicals #= "No Available",
   PostMessage( "Chemicals play an important role in crops sown under No-Till
methods. If requisite herbicide chemicals are not available conventional tillage suits.
Please enter more data." ) );
```

```
    /***********************************
     **** RULE: HarvestedCoRicWheat
     ***********************************/
MakeRule( HarvestedCoRicWheat, [x|Pakistan],
   ( x:Harvested #= Cotton ) Or ( x:Harvested #= Rice )
      Or ( x:Harvested #= Wheat ),
   PostMessage( "Information provided are not enough. Please enter more data." ) );

    /***********************************
     **** RULE: GrowCoRicWheat
     ***********************************/
MakeRule( GrowCoRicWheat, [x|Pakistan],
   ( x:Grow #= Cotton ) Or ( x:Grow #= Rice ) Or ( x:Grow #=
                                        Wheat ),
   PostMessage( "Information provided is not enough. Please enter more data." ) );

    /***********************************
     **** RULE: GrowCom1
     ***********************************/
MakeRule( GrowCom1, [x|Pakistan],
   x:GrowCom #= Yes,
   Execute( "C:\kappa\pkrotcom.doc" ) );

    /***********************************
     **** RULE: GrowCom2
     ***********************************/
MakeRule( GrowCom2, [x|Pakistan],
   x:GrowCom #= No,
   ShowWindow( Comments ) );

    /***********************************
     **** RULE: SoilCom1
     ***********************************/
MakeRule( SoilCom1, [x|Pakistan],
   x:SoilCom #= Yes,
   Execute( "C:\kappa\pksocom.doc" ) );

    /***********************************
     **** RULE: SoilCom2
     ***********************************/
MakeRule( SoilCom2, [x|Pakistan],
   x:SoilCom #= No,
   ShowWindow( Comments ) );

    /***********************************
     **** RULE: MoistureCom1
     ***********************************/
MakeRule( MoistureCom1, [x|Pakistan],
```

```
  x:MoistureCom #= Yes,
  Execute( "C:\kappa\pkmocom.doc" ) );

    /************************************
     **** RULE: MoistureCom2
     ************************************/
MakeRule( MoistureCom2, [x|Pakistan],
  x:MoistureCom #= No,
  ShowWindow( Comments ) );

    /************************************
     **** RULE: HarvestingCom1
     ************************************/
MakeRule( HarvestingCom1, [x|Pakistan],
  x:HarvestingCom #= Yes,
  Execute( "C:\kappa\pkharcom.doc" ) );

    /************************************
     **** RULE: HarvestingCom2
     ************************************/
MakeRule( HarvestingCom2, [x|Pakistan],
  x:HarvestingCom #= No,
  ShowWindow( Comments ) );

    /************************************
     **** RULE: SlopeCom1
     ************************************/
MakeRule( SlopeCom1, [x|Pakistan],
  x:SlopeCom #= Yes,
  Execute( "C:\kappa\pkslpcom.doc" ) );

    /************************************
     **** RULE: SlopeCom2
     ************************************/
MakeRule( SlopeCom2, [x|Pakistan],
  x:SlopeCom #= No,
  ShowWindow( Comments ) );

    /************************************
     **** RULE: ChemicalsCom1
     ************************************/
MakeRule( ChemicalsCom1, [x|Pakistan],
  x:ChemicalsCom #= Yes,
  Execute( "C:\kappa\pkchcom.doc" ) );

    /************************************
     **** RULE: ChemicalsCom2
     ************************************/
```

```
MakeRule( ChemicalsCom2, [x|Pakistan],
   x:ChemicalsCom #= No,
   ShowWindow( Comments ) );

    /*************************************
     **** RULE: TTCom1
     *************************************/
MakeRule( TTCom1, [x|Pakistan],
   x:TTCom #= Yes,
   Execute( "C:\kappa\pkttcom.doc" ) );

    /*************************************
     **** RULE: TTCom2
     *************************************/
MakeRule( TTCom2, [x|Pakistan],
   x:TTCom #= No,
   ShowWindow( Comments ) );

    /*************************************
     **** RULE: TractorCom1
     *************************************/
MakeRule( TractorCom1, [x|Pakistan],
   x:TractorCom #= Yes,
   Execute( "C:\kappa\pktrcom.doc" ) );

    /*************************************
     **** RULE: TractorCom2
     *************************************/
MakeRule( TractorCom2, [x|Pakistan],
   x:TractorCom #= No,
   ShowWindow( Comments ) );

    /*************************************
     **** RULE: DrillCom1
     *************************************/
MakeRule( DrillCom1, [x|Pakistan],
   x:DrillCom #= Yes,
   Execute( "C:\kappa\pkdrcom.doc" ) );

    /*************************************
     **** RULE: DrillCom2
     *************************************/
MakeRule( DrillCom2, [x|Pakistan],
   x:DrillCom #= No,
   ShowWindow( Comments ) );
```

```
   /************************************
    **** RULE: RSBCons
    ************************************/
MakeRule( RSBCons, [x|Pakistan],
•  x:Tillage #= "No-Till",
  {
  x:RSB = No;
  PostMessage( "RSB is not a risk and answer to if the farm is located in the RSB area
should be:   ",
     x:RSB );
  } );

   /************************************
    **** RULE: RSBConv
    ************************************/
MakeRule( RSBConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:RSB = Yes;
  PostMessage( "Farm is located in RSB risk area and the answer to if farm is located
in RSB area is in:  ",
     x:Chemicals );
  } );

   /************************************
    **** RULE: PesticidesCons
    ************************************/
MakeRule( PesticidesCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Pesticides = Available;
  PostMessage( "The required pesticides for RSB area seems to be   ",
     x:Pesticides );
  } );

   /************************************
    **** RULE: PesticidesConv
    ************************************/
MakeRule( PesticidesConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Pesticides = "Not  available";
  PostMessage( "The required herbicides chemicals seem  to be ",
     x:Pesticides );
  } );
```

```
    /************************************
     **** RULE: PesticidesCom2
     ************************************/
MakeRule( PesticidesCom2, [x|Pakistan],
   x:PesticidesCom #= No,
   ShowWindow( Comments ) );

    /************************************
     **** RULE: RSBCom1
     ************************************/
MakeRule( RSBCom1, [x|Pakistan],
   x:RSBCom #= Yes,
   Execute( "C:\kappa\pkrsbcom.doc" ) );

    /************************************
     **** RULE: RSBCom2
     ************************************/
MakeRule( RSBCom2, [x|Pakistan],
   x:RSBCom #= No,
   ShowWindow( Comments ) );

    /************************************
     **** RULE: PesticidesCom1
     ************************************/
MakeRule( PesticidesCom1, [x|Pakistan],
   x:PesticidesCom #= Yes,
   Execute( "C:\kappa\pkpstcom.doc" ) );

    /************************************
     **** RULE: DrillAvail
     ************************************/
MakeRule( DrillAvail, [x|Pakistan],
   x:Drill #= Available,
   PostMessage( "If farmer has access to a direct-drill which can work in local
conditions, and can penetrate into straw residue (if left), then No-Till suits. Please enter
more data." ) );

    /************************************
     **** RULE: DrillNotAvail
     ************************************/
MakeRule( DrillNotAvail, [x|Pakistan],
   x:Drill #= "Not Available",
   PostMessage( "If farmer has not any access to a No-Till drill, conventional tillage
method should continue. Please enter more data." ) );

    /************************************
     **** RULE: VarietyCons
     ************************************/
```

```
MakeRule( VarietyCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
   x:Variety = "Early maturing or mid maturing";
   PostMessage( "The harvested rice variety should either  be   ",
      x:Variety );
   } );

     /************************************
      ****  RULE: VarietyConv
•      ************************************/
MakeRule( VarietyConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Variety = "Late maturing";
   PostMessage( "The harvested rice variety should be ", x:Variety );
   } );

     /************************************
      ****  RULE: SoilLoam
      ************************************/
MakeRule( SoilLoam, [x|Pakistan],
   x:Soil #= Sandy Or x:Soil #= "Silt Loam",
   PostMessage( "Sandy to Sandy Loam and Silt Loam soils are suited to No-Till.
Generally, all well drained soils are also suitable for No-Till cropping. Please enter more
data." ) );

     /************************************
      ****  RULE: VarietyLate
      ************************************/
MakeRule( VarietyLate, [x|Pakistan],
   x:Variety #= "Late maturing",
   PostMessage( "To overcome the delay in planting of wheat after Rice and Cotton,
No-Till is encouraged. Thus, late maturing rice varieties force farmer for No-Till. Please
enter more data." ) );

     /************************************
      ****  RULE: VarietyCom1
      ************************************/
MakeRule( VarietyCom1, [x|Pakistan],
   x:VarietyCom #= Yes,
   Execute( "C:\kappa\pkvarcom.doc" ) );

     /************************************
      ****  RULE: VarietyCom2
      ************************************/
MakeRule( VarietyCom2, [x|Pakistan],
   x:VarietyCom #= No,
```

```
ShowWindow( Comments ) );

/************************************
 **** RULE: StrawRemoved
 ************************************/
MakeRule( StrawRemoved, [x|Pakistan],
  x:Harvesting #= Removed,
  PostMessage( "If straw residue from previous crop was removed,  direct-drill is
vailable, and seed micro-environment is also moist or wetter, No-Till suits. Please enter
more data." ) );

/************************************
 **** RULE: SlopeMedium
 ************************************/
MakeRule( SlopeMedium, [x|Pakistan],
  x:Slope #= "Medium(5-12%)",
  PostMessage( "If slope is high, meaning from 5 to 12%, and direct-drill is also
available, No-Till is more suitable. Please enter more data." ) );

/************************************
 **** RULE: SlopeHigh
 ************************************/
MakeRule( SlopeHigh, [x|Pakistan],
•  x:Slope #= "High(>12%)",
•  PostMessage( "If slope is high, meaning more than 12%, and direct-drill is also
available, and tractor can negotiate slopes, then No-Till is suitable. Please enter more
data." ) );

/************************************
 **** RULE: MoistureDry
 ************************************/
MakeRule( MoistureDry, [x|Pakistan],
  x:Moisture #= Dry,
  PostMessage( "If the soil around seed micro-environment is dry, and no suitable
direct-drill is available for seeding, then conventional tillage suits. Please enter more
data." ) );

/************************************
 **** RULE: StoneLar
 ************************************/
MakeRule( StoneLar, [x|Drills],
  x:DrillTypes #= "Stone (large) texture",
  PostMessage( "Heavy duty direct drills with parallel floating drag arms having winged
openers are suitable under such conditions." ) );

/************************************
 **** RULE: StoneMed
 ************************************/
```

```
MakeRule( StoneMed, [x|Drills],
   x:DrillTypes #= "Stone (medium) texture",
   PostMessage( "Light drills with spring tine legs and limited depth control winged or
hoe openers are suitable under such conditions." ) );

     /************************************
      **** RULE: StandStubble
      *************************************/
MakeRule( StandStubble, [x|Drills],
   x:DrillTypes #= "Standing stubble",
   PostMessage( "Light or heavy duty direct drills with parallel floating drag arms
having winged or hoe openers are suitable under such conditions." ) );

     /************************************
      **** RULE: LyingResidue
      *************************************/
MakeRule( LyingResidue, [x|Drills],
   x:DrillTypes #= "Lying residue",
   PostMessage( "Conventional drills with floating arms or any heavy duty direct drill
with floating drag arms are suitable under such conditions." ) );

     /************************************
      **** RULE: BareSoil
      *************************************/
MakeRule( BareSoil, [x|Drills],
   x:DrillTypes #= "Bare soil, short pasture",
   PostMessage( "Light or heavy duty drills with spring tine legs, floating drag arms, and
limited depth control having winged or hoe openers are suitable under such conditions."
) );

     /************************************
      **** RULE: ConvenTill
      *************************************/
MakeRule( ConvenTill, [x|Drills],
   x:DrillTypes #= "Conventional-Tillage",
   ShowWindow( SESSION ) );
```

Rules from File: PKW.kal

```
/************************************
      **** RULE: Rule2
      *************************************/
MakeRule( Rule2, [x|Pakistan],
   ( x:Grow #= Rice Or x:Grow #= Cotton ) And ( x:Harvested #=
                                        Wheat )
      And ( x:Soil #= Clayey ) And ( x:Drill #= "Not Available" )
      And ( x:Chemicals #= "Not Available" ) And ( x:RSB #= Yes )
      And ( x:Pesticides #= "Not Available" ) And ( x:Harvesting
```

```
                                    #= Removed )
      And ( x:Moisture #= Dry ) And ( x:TTransfer #= Bad )
      And ( x:Tractor #= "More than 70HP" ) And ( x:Slope #= "Low(<5%)" ),
   PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques. For further details please press button <Please
explain> and read appropriate explanation." ) );

     /************************************
      ****  RULE: Rule4
      ************************************/
MakeRule( Rule4, [x|Pakistan],
   (x:Harvested #= Cotton And x:Grow #= Cotton)( x:Harvested
                                    #= Cotton
                                    And x:Grow
                                    #= Rice )
      Or ((((x:Harvested #= Rice And x:Grow #= Cotton)(
            x:Harvested #= Rice And x:Grow #= Rice ))( x:Harvested
                                         #=
                                         Wheat
                                         And
                                         x:Grow
                                         #=
                                         Cotton ))( x:Harvested
                                                #=
                                                Wheat
                                                And
                                                x:Grow
                                                #=
                                                Rice ))( x:Harvested
                                                      #=
                                                      Wheat
                                                      And
                                                      x:Grow
                                                      #=
                                                      Cotton )
      Or ( x:Grow #= Cotton ) Or ( x:Grow #= Rice )
      Or ( x:Harvested #= Wheat ) Or ( x:Soil #= Clayey )
      Or ( x:Drill #= "Not Available" ) Or ( x:Chemicals #= "Not Available" )
      Or ( x:RSB #= Yes And x:Chemicals #= "Not Available" )
      Or ( x:Pesticides #= "Not Available" ),
   PostMessage( "The given condition(s) suggest that farmer should continue with
Conventional-Tillage techniques. For further details please press button <Please
explain> and read appropriate explanation." ) );

     /************************************
      ****  RULE: Rule3
      ************************************/
MakeRule( Rule3, [x|Pakistan],
```

```
  ( x:Harvested #= Cotton And x:Grow #= Wheat ) Or ( x:Harvested
                                             #=
                                             Rice
                                             And
                                             x:Grow
                                             #=
                                             Wheat )
    Or ( x:Soil #= Sandy Or x:Soil #= "Silt Loam" )
    Or ( x:Drill #= Available ) Or ( x:Chemicals #= Available )
    Or ( x:RSB #= No ) Or ( x:RSB #= Yes And x:Pesticides
                   #= Available ) Or ( x:Harvesting
                                             #=
                                             "Left on surface" )
    Or ( x:TTransfer #= Excellent Or x:TTransfer #= Good )
    Or ( x:Tractor #= "Range 45-70HP" ) Or ( x:Slope #= "Medium(5-12%)"
                                        Or x:Slope
                                        #= "High(>12%)" ),
  PostMessage( "Under selected conditions No-Tillage suits. For further details please
press button <Please explain> and read appropriate explanation." ) );

    /************************************
    **** RULE: Rule1
    ************************************/
MakeRule( Rule1, [x|Pakistan],
  ( x:Grow #= Wheat ) And ( x:Harvested #= Rice Or x:Harvested
                  #= Cotton ) And ( x:Soil #=
                                          Sandy
                                          Or x:Soil
                                          #= "Silt Loam" )
    And ( x:Drill #= Available ) And ( x:Chemicals #= Available )
    And ( x:RSB #= No ) And ( x:Pesticides #= Available )
    And ( x:Harvesting #= "Left on surface" ) And ( x:Moisture
                                           #= Moist )
    And ( x:TTransfer #= Excellent Or x:TTransfer #= Good )
    And ( x:Tractor #= "Range 45-70HP" ) And ( x:Slope #= "Medium(5-12%)"
                                         Or x:Slope
                                         #= "High(>12%)" ),
  PostMessage( "Under selected conditions No-Tillage suits. For further details please
press button <Please explain> and read appropriate explanation." ) );

    /************************************
    **** RULE: SoilCons
    ************************************/
MakeRule( SoilCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Soil = "Sandy Or Silt Loam";
  PostMessage( "The soil texture should to be either  ", x:Soil );
```

```
  /************************************
   **** RULE: SoilConv
   ************************************/
MakeRule( SoilConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Soil = Clayey;
  PostMessage( "The soil texture seems to be  ", x:Soil );
  } );

  /************************************
   **** RULE: GrowCons
   ************************************/
MakeRule( GrowCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Grow = Wheat;
  PostMessage( "The  crop to be grown should be  ", x:Grow );
  } );

  /************************************
   **** RULE: GrowConv
   ************************************/
MakeRule( GrowConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Grow = "Rice Or Cotton";
  PostMessage( "The next crop grown should either be  ", x:Grow );
  } );

  /************************************
   **** RULE: DrillCons
   ************************************/
MakeRule( DrillCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Drill = Available;
  PostMessage( "The No-Till  drill should be  ", x:Drill );
  } );

  /************************************
   **** RULE: DrillConv
   ************************************/
MakeRule( DrillConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Drill = "Not available";
  PostMessage( "The No-Till  drill seems to be  ", x:Drill );
```

```
  /************************************
   **** RULE: TractorCons
  ************************************/
MakeRule( TractorCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Tractor = "Range 45-70HP";
  PostMessage( "Tractor power available should  ", x:Tractor );
  } );

  /************************************
   **** RULE: TractorConv
   ************************************/
MakeRule( TractorConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Tractor = "More than 70HP";
  PostMessage( "Tractor available power seems to be ", x:Tractor );
  } );

  /************************************
   **** RULE: TTransferCons
  ************************************/
MakeRule( TTransferCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:TTransfer = "Excellent Or Good";
  PostMessage( "The level of extension facilities should be either ",
     x:TTransfer );
  } );

  /************************************
   **** RULE: TTransferConv
   ************************************/
MakeRule( TTransferConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:TTransfer = Bad;
  PostMessage( "The level of extension facilities available is rated as  ",
     x:TTransfer );
  } );

  /************************************
   **** RULE: ChemicalsCons
   ************************************/
MakeRule( ChemicalsCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
```

```
  x:Chemicals = Available;
  PostMessage( "The herbicides chemical should be   ", x:Chemicals );
  } );
    /*************************************
     **** RULE: ChemicalsConv
     *************************************/
MakeRule( ChemicalsConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Chemicals = "Not  available";
  PostMessage( "The required herbicides chemicals seem  to be ",
     x:Chemicals );
  } );

    /*************************************
     **** RULE: HarvestingCons
     *************************************/
MakeRule( HarvestingCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Harvesting = "Left on surface";
  PostMessage( "The previous crop residue should be  ", x:Harvesting );
  } );
    /*************************************
     **** RULE: HarvestingConv
     *************************************/
MakeRule( HarvestingConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvesting = Removed;
  PostMessage( "From  previous crop residue should have been  ",
     x:Harvesting );
  } );
    /*************************************
     **** RULE: MoistureCons
     *************************************/
MakeRule( MoistureCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Moisture = Moist;
  PostMessage( "The soil moisture at the time of planting should be  ",
     x:Moisture );
  } );

    /*************************************
     **** RULE: MoistureConv
     *************************************/
MakeRule( MoistureConv, [x|Pakistan],
```

```
  x:Tillage #= "Conventional-Tillage",
  {
  x:Moisture = Dry;
  PostMessage( "The soil moisture at time of planting should be  ",
    x:Moisture );
  } );

    /************************************
     **** RULE: HarvestedCons
     ************************************/
MakeRule( HarvestedCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Harvested = "Rice Or Cotton";
  PostMessage( "The harvested crop should  either be  ", x:Harvested );
  } );

    /************************************
     **** RULE: HarvestedConv
     ************************************/
MakeRule( HarvestedConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Harvested = Wheat;
  PostMessage( "The harvested crop seems to be ", x:Harvested );
  } );

    /************************************
     **** RULE: SlopeCons
     ************************************/
MakeRule( SlopeCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:Slope = "Medium(5-12%) Or High(>12%)";
  PostMessage( "The slope of  the field should be ", x:Slope );
  } );

    /************************************
     **** RULE: SlopeConv
     ************************************/
MakeRule( SlopeConv, [x|Pakistan],
  x:Tillage #= "Conventional-Tillage",
  {
  x:Slope = "Low(<50%)";
  PostMessage( "Slope of  the field  seems to be ", x:Slope );
  } );
```

```
/*************************************
 **** RULE: GrowCoRicWheat
 *************************************/
MakeRule( GrowCoRicWheat, [x|Pakistan],
  ( x:Grow #= Cotton ) Or ( x:Grow #= Rice ) Or ( x:Grow #=
                                        Wheat ),
  PostMessage( "The information provided is not enough. Please enter more data." ) ;

/*************************************
 **** RULE: SoilClayey
 *************************************/
MakeRule( SoilClayey, [x|Pakistan],
  x:Soil #= Clayey,
  PostMessage( "Undrained clayey soils are not suitable for adoption of No-Till.
However, if drained, could be suitable for No-Till. Please enter more data." ) );

/*************************************
 **** RULE: SoilLoam
 *************************************/
MakeRule( SoilLoam, [x|Pakistan],
  x:Soil #= Sandy Or x:Soil #= "Silt Loam",
  PostMessage( "Sandy to Sandy Loam and Silt Loam soils are suited to No-Till.
Generally, all well drained soils are suitable for No-Till cropping. Please enter more
data." ) );

/*************************************
 **** RULE: HarvestedCoRicWheat
 *************************************/
MakeRule( HarvestedCoRicWheat, [x|Pakistan],
  ( x:Harvested #= Cotton ) Or ( x:Harvested #= Rice )
    Or ( x:Harvested #= Wheat ),
  PostMessage( "The information provided is not enough. Please enter more data." );

/*************************************
 **** RULE: StrawLeft
 *************************************/
MakeRule( StrawLeft, [x|Pakistan],
  x:Harvesting #= "Left on surface",
  PostMessage( "If straw residue from previous crop was left on the surface, and a
direct-drill is available then No-Till is suitable. Please enter more data." ) );

/*************************************
 **** RULE: MoistureMoist
 *************************************/
MakeRule( MoistureMoist, [x|Pakistan],
  x:Moisture #= Moist,
```

```
   PostMessage( "If the soil around seed micro-environment is moist or wetter, and a
suitable direct-drill is also available for seeding, then No-Till suits. Please enter more
data." ) );

    /*************************************
     **** RULE: MoistureDry
     *************************************/
MakeRule( MoistureDry, [x|Pakistan],
   x:Moisture #= Dry,
   PostMessage( "If the soil around seed micro-environment is dry, and no suitable
direct-drill is available for seeding, then conventional tillage suits. Please enter more
data." ) );

    /*************************************
     **** RULE: SlopeMedium
     *************************************/
MakeRule( SlopeMedium, [x|Pakistan],
   x:Slope #= "Medium(5-12%)",
   PostMessage( "If slope is medium, meaning from 5 to 12%, and direct-drill is also
available, No-Till is more suitable. Please enter more data." ) );

    /*************************************
     **** RULE: SlopeHigh
     *************************************/
MakeRule( SlopeHigh, [x|Pakistan],
   x:Slope #= "High(>12%)",
   PostMessage( "If slope is high, meaning more than 12%, and direct-drill is also
available, and tractor can negotiate slopes, then No-Till is most suitable. Please enter
more data." ) );

    /*************************************
     **** RULE: TTGood
     *************************************/
MakeRule( TTGood, [x|Pakistan],
   x:TTransfer #= Excellent Or x:TTransfer #= Good,
   PostMessage( "If the local agricultural extension is providing good information w.r.t.
No-Till (for pesticide, herbicides application etc.), then No-Till suits. Please enter more
data." ) );

    /*************************************
     **** RULE: TTBad
     *************************************/
MakeRule( TTBad, [x|Pakistan],
   x:TTransfer #= Bad,
   PostMessage( "If the local agricultural extension is not well aware with information
w.r.t. No-Till (for pesticide, herbicide application etc.), then conventional tillage suits.
Please enter more data." ) );
```

```
/************************************
 **** RULE: RSBNo
 ************************************/
MakeRule( RSBNo, [x|Pakistan],
  x:RSB #= No,
  PostMessage( "If farm is not RSB affected then No-Till can be adopted. If it is within RSB affected zone but requisite pesticides are available, No-Till can be considered. Please enter more data." ) );

/************************************
 **** RULE: RSBYes
 ************************************/
MakeRule( RSBYes, [x|Pakistan],
  x:RSB #= Yes,
  PostMessage( "In case farm is affected by RSB and requisite pesticides are not available, conventional tillage suits. However, if pesticides are available, No-Till can also be considered. Please enter more data." ) );

/************************************
 **** RULE: ChemicalsAvail
 ************************************/
MakeRule( ChemicalsAvail, [x|Pakistan],
  x:Chemicals #= Available,
  PostMessage( "Chemicals play an important role in crops sown under No-Till methods. Availability of requisite herbicide chemicals is essential for adopting No-Till. Please enter more data." ) );

/************************************
 **** RULE: ChemicalsNotAvail
 ************************************/
MakeRule( ChemicalsNotAvail, [x|Pakistan],
  x:Chemicals #= "Not Available",
  PostMessage( "Chemicals play an important role in crops sown under No-Till methods. If  requisite herbicide chemicals are not available, conventional tillage suits. Please enter more data." ) );

/************************************
 **** RULE: TractorSmall
 ************************************/
MakeRule( TractorSmall, [x|Pakistan],
  x:Tractor #= "Range 45-70HP",
  PostMessage( "Farmers having tractors 45-70HP range are generally have low land holding capacity. These are the farmers who need to adopt No-Till. Please enter more data." ) );

/************************************
 **** RULE: TractorLarge
 ************************************/
```

```
MakeRule( TractorLarge, [x|Pakistan],
   x:Tractor #= "More than 70HP",
   PostMessage( "Farmers with bigger tractors (>70HP) may also have other range of
agricultural equipment. No-Till or conventional methods, either can suit, depending
upon other factors. Please enter more data." ) );

     /************************************
      **** RULE: GrowCom1
      ************************************/
MakeRule( GrowCom1, [x|Pakistan],
   x:GrowCom #= Yes,
   Execute( "C:\kappa\pkrotcom.doc" ) );

     /************************************
      **** RULE: GrowCom2
      ************************************/
MakeRule( GrowCom2, [x|Pakistan],
   x:GrowCom #= No,
   ShowWindow( Comments ) );

     /************************************
      **** RULE: SoilCom1
     ************************************/
MakeRule( SoilCom1, [x|Pakistan],
   x:SoilCom #= Yes,
   Execute( "C:\kappa\pksocom.doc" ) );

     /************************************
      **** RULE: SoilCom2
      ************************************/
MakeRule( SoilCom2, [x|Pakistan],
   x:SoilCom #= No,
   ShowWindow( Comments ) );

     /************************************
      **** RULE: MoistureCom1
      ************************************/
MakeRule( MoistureCom1, [x|Pakistan],
   x:MoistureCom #= Yes,
  Execute( "C:\kappa\pkmocom.doc" ) );

     /************************************
      **** RULE: MoistureCom2
      ************************************/
MakeRule( MoistureCom2, [x|Pakistan],
   x:MoistureCom #= No,
  ShowWindow( Comments ) );
```

```
   /************************************
    **** RULE: HarvestingCom1
    ************************************/
MakeRule( HarvestingCom1, [x|Pakistan],
  x:HarvestingCom #= Yes,
  Execute( "C:\kappa\pkharcom.doc" ) );

   /************************************
    **** RULE: HarvestingCom2
    ************************************/
MakeRule( HarvestingCom2, [x|Pakistan],
  x:HarvestingCom #= No,
  ShowWindow( Comments ) );

   /************************************
    **** RULE: SlopeCom1
    ************************************/
MakeRule( SlopeCom1, [x|Pakistan],
  x:SlopeCom #= Yes,
  Execute( "C:\kappa\pkslpcom.doc" ) );

   /************************************
    **** RULE: SlopeCom2
    ************************************/
MakeRule( SlopeCom2, [x|Pakistan],
  x:SlopeCom #= No,
  ShowWindow( Comments ) );

   /************************************
    **** RULE: ChemicalsCom1
    ************************************/
MakeRule( ChemicalsCom1, [x|Pakistan],
  x:ChemicalsCom #= Yes,
  Execute( "C:\kappa\pkchcom.doc" ) );
   /************************************
    **** RULE: ChemicalsCom2
    ************************************/
MakeRule( ChemicalsCom2, [x|Pakistan],
  x:ChemicalsCom #= No,
  ShowWindow( Comments ) );

   /************************************
    **** RULE: TTCom1
    ************************************/
MakeRule( TTCom1, [x|Pakistan],
  x:TTCom #= Yes,
  Execute( "C:\kappa\pkttcom.doc" ) );
```

```
/************************************
 **** RULE: TTCom2
 ************************************/
MakeRule( TTCom2, [x|Pakistan],
  x:TTCom #= No,
  ShowWindow( Comments ) );

/************************************
 **** RULE: TractorCom1
 ************************************/
MakeRule( TractorCom1, [x|Pakistan],
  x:TractorCom #= Yes,
  Execute( "C:\kappa\pktrcom.doc" ) );

/************************************
 **** RULE: TractorCom2
 ************************************/
MakeRule( TractorCom2, [x|Pakistan],
  x:TractorCom #= No,
  ShowWindow( Comments ) );

/************************************
 **** RULE: DrillCom1
 ************************************/
MakeRule( DrillCom1, [x|Pakistan],
  x:DrillCom #= Yes,
 Execute( "C:\kappa\pkdrcom.doc" ) );

/************************************
 **** RULE: DrillCom2
 ************************************/
MakeRule( DrillCom2, [x|Pakistan],
  x:DrillCom #= No,
  ShowWindow( Comments ) );

/************************************
 **** RULE: RSBCons
 ************************************/
MakeRule( RSBCons, [x|Pakistan],
  x:Tillage #= "No-Till",
  {
  x:RSB = No;
 PostMessage( "RSB is not a risk and answer to if the farm is located in the RSB area
should be:   ",
    x:RSB );
  } );
```

```
/*************************************
**** RULE: RSBConv
*************************************/
MakeRule( RSBConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:RSB = Yes;
   PostMessage( "Farm is located in RSB risk area and the answer to if farm is located
in RSB area is in: ",
      x:Chemicals );
   } );

/*************************************
**** RULE: PesticidesCons
*************************************/
MakeRule( PesticidesCons, [x|Pakistan],
   x:Tillage #= "No-Till",
   {
  x:Pesticides = Available;
   PostMessage( "The required pesticides for RSB area seems to be   ",
      x:Pesticides );
   } );

/*************************************
**** RULE: PesticidesConv
*************************************/
MakeRule( PesticidesConv, [x|Pakistan],
   x:Tillage #= "Conventional-Tillage",
   {
   x:Pesticides = "Not  available";
  PostMessage( "The required herbicides chemicals seem  to be ",
      x:Pesticides );
   } );

/*************************************
**** RULE: PesticidesCom2
*************************************/
akeRule( PesticidesCom2, [x|Pakistan],
   x:PesticidesCom #= No,
   ShowWindow( Comments ) );

/*************************************
**** RULE: RSBCom1
*************************************/
MakeRule( RSBCom1, [x|Pakistan],
  x:RSBCom #= Yes,
   Execute( "C:\kappa\pkrsbcom.doc" ) );
```

```
    /************************************
     **** RULE: RSBCom2
     ************************************/
MakeRule( RSBCom2, [x|Pakistan],
   x:RSBCom #= No,
   ShowWindow( Comments ) );

    /************************************
     **** RULE: PesticidesCom1
     ************************************/
MakeRule( PesticidesCom1, [x|Pakistan],
   x:PesticidesCom #= Yes,
  Execute( "C:\kappa\pkpstcom.doc" ) );

    /************************************
     **** RULE: DrillAvail
     ************************************/
MakeRule( DrillAvail, [x|Pakistan],
   x:Drill #= Available,
   PostMessage( "If farmer has access to a direct-drill which can work in local
conditions, and can penetrate into straw residue (if left), and other conditions also
favour then No-Till suits. Please enter more data." ) );
    /************************************
     **** RULE: DrillNotAvail
     ************************************/
MakeRule( DrillNotAvail, [x|Pakistan],
   x:Drill #= "Not Available",
   PostMessage( "If farmer has not access to a direct-drill then conventional tillage
method should continue until circumstances are changed.  Please enter more data." ) );

    /************************************
     **** RULE: PesticidesAvail
     ************************************/
MakeRule( PesticidesAvail, [x|Pakistan],
   x:Pesticides #= Available,
   PostMessage( "If pesticides are available to destroy pests from the previous crop, and
all other conditions also favour then No-Till can be adopted. Please enter more data." )
);

    /************************************
     **** RULE: PesticidesNotAvail
     ************************************/
MakeRule( PesticidesNotAvail, [x|Pakistan],
   x:Pesticides #= "Not Available",
   PostMessage( "If pesticides are not available to destroy pests from the previous crop
then No-Till is not suitable. Please enter more data." ) );
```

```
/************************************
 **** RULE: StrawRemoved
 ************************************/
MakeRule( StrawRemoved, [x|Pakistan],
   x:Harvesting #= Removed,
   PostMessage( "If straw residue from previous crop was removed and a direct-drill is available and seed micro-environment is also moist or wetter, then No-Till suits. Please enter more data." ) );

/************************************
 **** RULE: SlopeLow
 ************************************/
MakeRule( SlopeLow, [x|Pakistan],
   x:Slope #= "Low(<5%)",
   PostMessage( "If field is flat, or slope is Low, meaning less than 5%, and a direct-drill is also available, No-Till or conventional methods both are suitable. Please enter more data." ) );

/************************************
 **** RULE: StoneLar
 ************************************/
MakeRule( StoneLar, [x|Drills],
   x:DrillTypes #= "Stone (large) texture",
   PostMessage( "Heavy duty direct drills with parallel floating drag arms having winged openers are suitable under such conditions" ) );

/************************************
 **** RULE: StoneMed
 ************************************/
MakeRule( StoneMed, [x|Drills],
   x:DrillTypes #= "Stone (medium) texture",
   PostMessage( "Light drills with spring tine legs and limited depth control winged or hoe openers are suitable under such conditions" ) );

/************************************
 **** RULE: StandStubble
 ************************************/
MakeRule( StandStubble, [x|Drills],
  x:DrillTypes #= "Standing stubble",
   PostMessage( "Light or heavy duty direct drill with parallel floating drag arms having winged or hoe openers are suitable under such conditions" ) );

/************************************
 **** RULE: LyingResidue
 ************************************/
MakeRule( LyingResidue, [x|Drills],
   x:DrillTypes #= "Lying residue",
```

```
  PostMessage( "Conventional drills with floating drag arms or any heavy duty direct
drill with floating drag arms are suitable under such conditions" ) );

     /************************************
      **** RULE: BareSoil
      ************************************/
MakeRule( BareSoil, [x|Drills],
   x:DrillTypes #= "Bare soil, short pasture",
   PostMessage( "Light or heavy duty drills with spring tine legs, or floating drag arms
and limited depth control having winged or hoe openers are suitable under such
conditions" ) );

     /************************************
      **** RULE: ConvenTill
      ************************************/
MakeRule( ConvenTill, [x|Drills],
   x:DrillTypes #= "Conventional-Tillage",
   ShowWindow( SESSION ) );
```

User's Guide

No-Till Expert System

(NOTE)

An effort to introduce No-Till technique using a computer aided decision support system

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1. Introduction

No-Till Expert (NOTE) is a computer-based decision support system (DSS) designed to help farmers and the agricultural extension agents either to choose or reject No-Till under the given conditions. NOTE in its current shape is valid for the following situations:

- Rice-Wheat or Cotton-Wheat cropping systems in Pakistan
- Pasture over-drilling in New Zealand

Information and the data used in NOTE are based on the knowledge and experiences of the universities and the research organisation(s). NOTE works just as a human expert would work if consulted about the best tillage system for the given conditions. Maximum efforts have been made to ensure that the program at any stage is not prejudiced towards (or against) any of the tillage techniques under consideration. Therefore, just like the human expert, NOTE asks a series of questions from its user, and with response to the few initial questions determines what it asks next. Following this process NOTE finally recommends either the acceptance of No-Till or the continuation with conventional tillage practices.

2. System requirements

NOTE is designed to run on Windows. It is based around a Kappa-PC[1] shell. Thus, availability of this software is an initial requirement. Kappa-PC runs on any monochrome screen having resolutions equal or above 640x350. It can be installed on a 386 or 486 based computer.

3. Printer requirements

Though the program does not require a printer because all results are displayed on the screen, however, if a permanent record is desired, a hard copy of all the recommendations that appear on the screen may be printed after the program is completed. Instructions are displayed on the screen guiding the user on how to get a print of the recommendation that is automatically generated and saved in a Microsoft Words file[(+)]. The option of saving the file in Microsoft Word can be changed by editing few files that are explained elsewhere in this user guide.

[+]NOTE: If you wish to keep the contents of the file which are generated automatically, please rename it before executing NOTE again; otherwise, the file will be "over-written" with the new values and recommendations.

4. Getting Started

As mentioned in the system requirements, the user would require to download Kappa-PC software. Kappa-PC is available in two diskettes. Insert diskette 1 and start

1 Mention of trademarks or vendors do not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

installation by executing a:\setup file. Diskette 2 will also be needed once installation is in progress. After installing Kappa-PC, please insert the diskette containing NOTE.

4.1 How to run NOTE?

PART-I

Step 1

Go to the File menu and open file named "country.kal" (Figure 1).

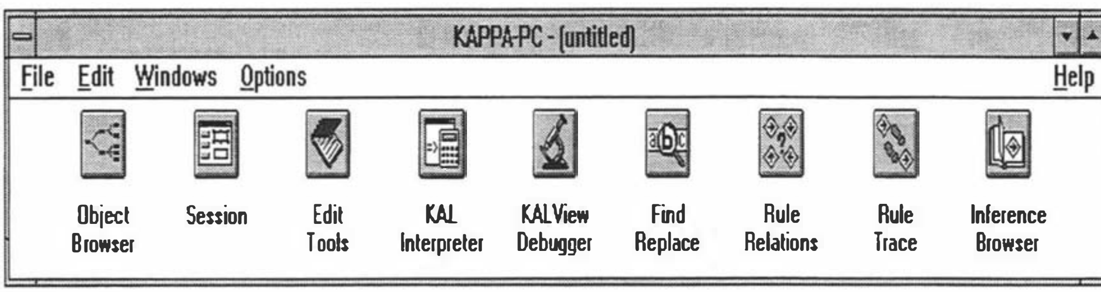

Figure 1

The screen then should appear as in Figure 2.

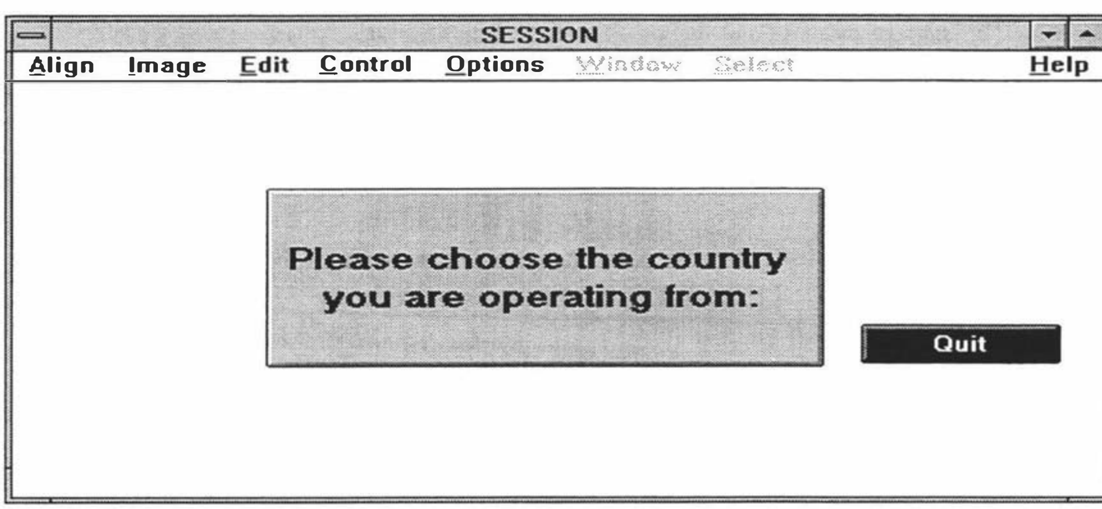

Figure 2

Click the box button titled "**Please choose the country you are operating from**".

Two options (Pakistan, and New Zealand) appear in a dialogue box (Figure 3). Please choose one.

Once an options is selected, click "OK", and NOTE executes the respective portion of the expert system. Let us assume, the user has chosen "New Zealand".

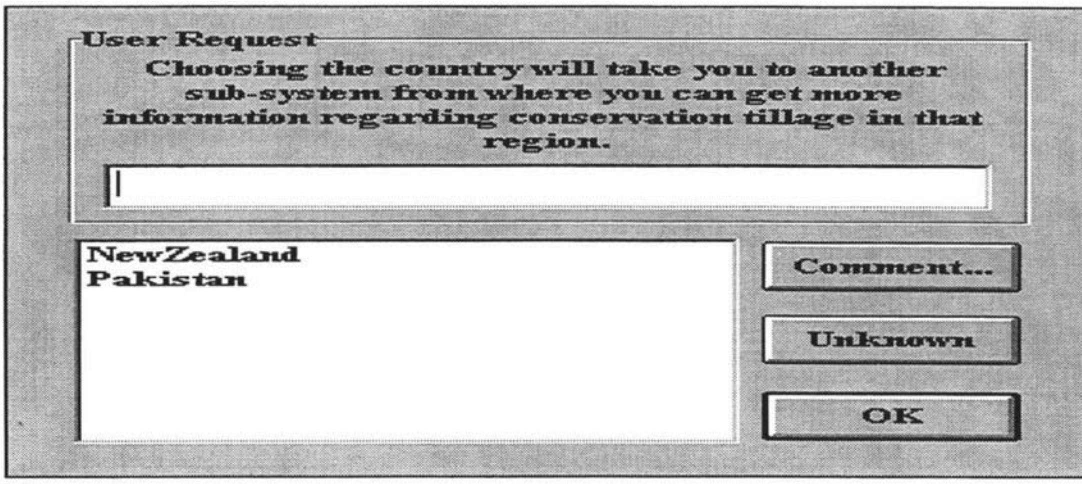

Figure 3

Step 2

NOTE would now execute a file named as "NZ.kal", and the screen should appear like as in Figure 4.

Figure 4

NOTE asks the user to enter the standing (or previously harvested) crop. Two options (cereals, and pasture) appear in the dialogue box (Figure 5).

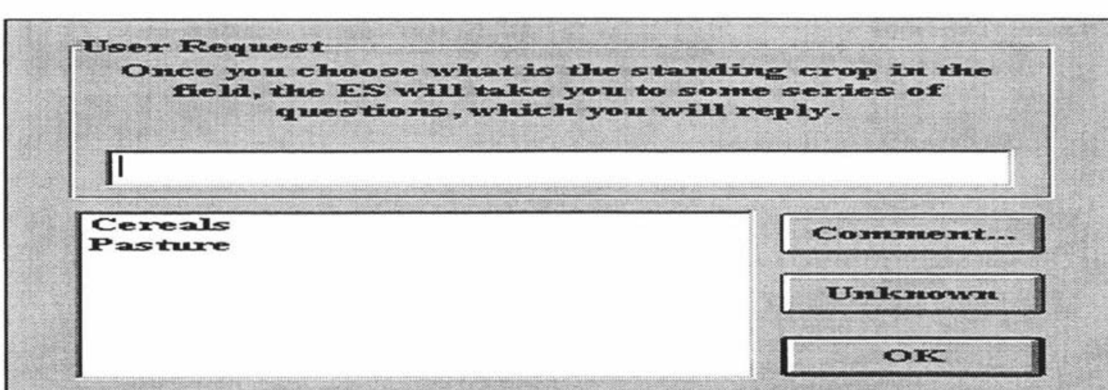

Figure 5

Please enter one of the options, and click "OK".

Step 3

Let us assume the user has opted for "pasture". NOTE will execute a file named "NZP.kal", and the screen should appear as in the Figure 6.

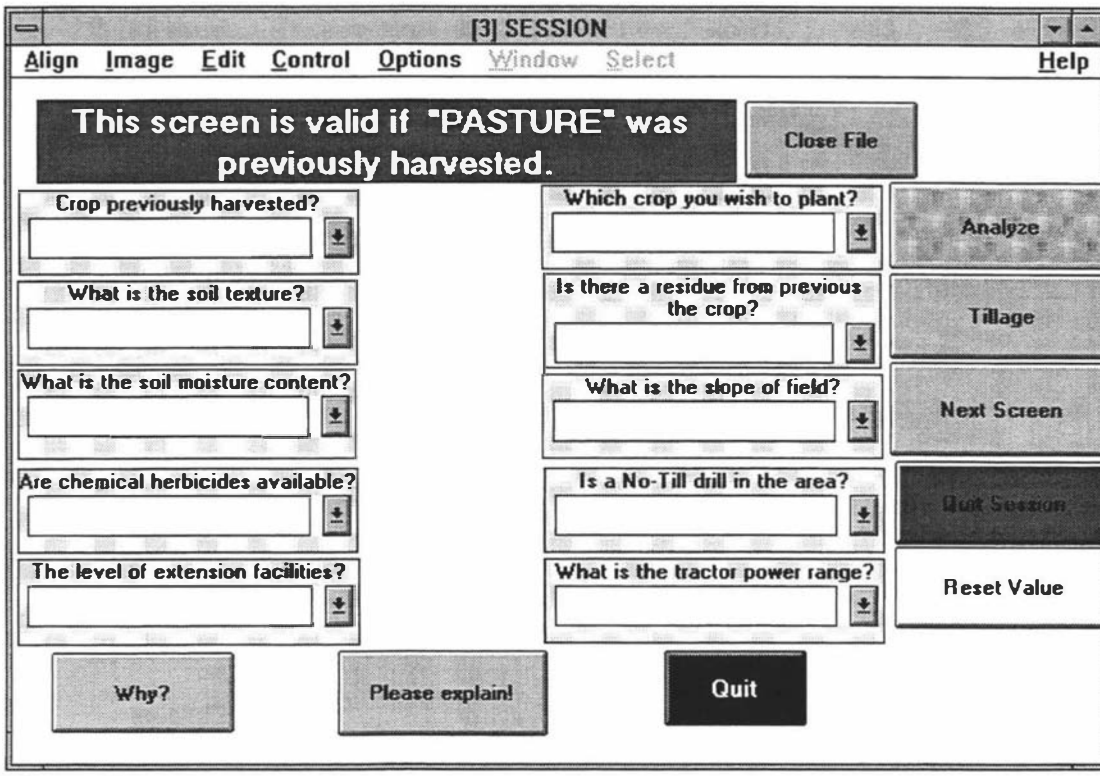

Figure 6

Each dialogue box has appropriate values. Please select a value in each dialogue box. After entering all the values (NOTE can be asked to recommend suitable tillage technique at any stage even before entering values in all boxes, however, it is recommended to enter the maximum number of values), then click the button named "Analyze". Depending on the data entered, one of the following recommendation will appear onto the screen (Figure 7 and Figure 8).

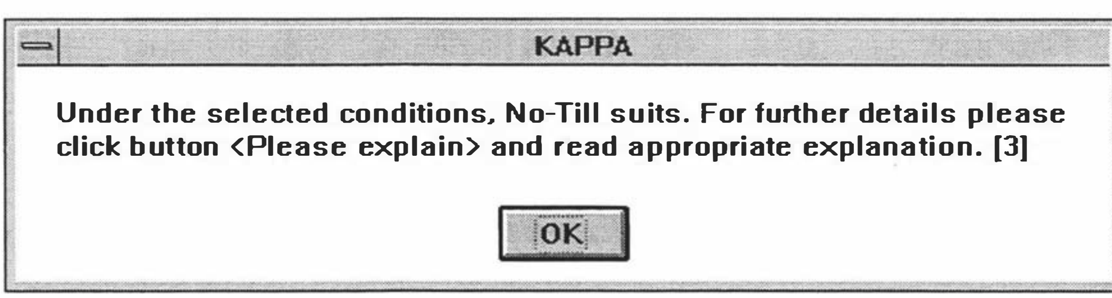

Figure 7

Or

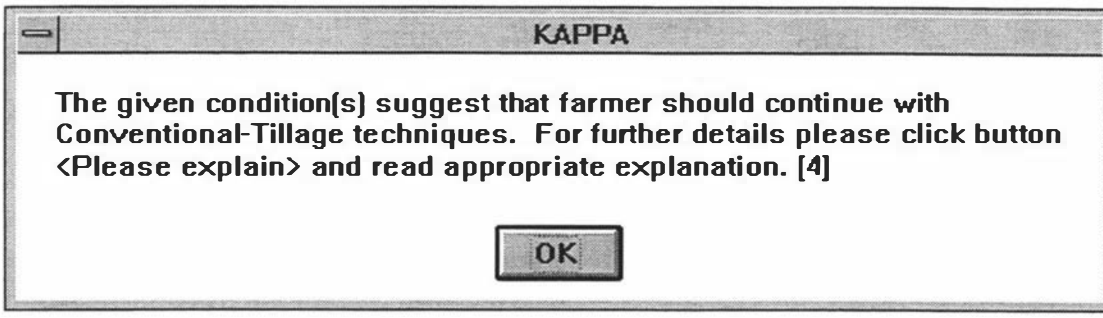

Figure 8

However, if all dialogue boxes were not entered with appropriate values, and NOTE was asked to "Analyze" with only few input values, then message may read as shown in Figure 9 or Figure 10.

(For example, only soil type and the crop rotation were entered)

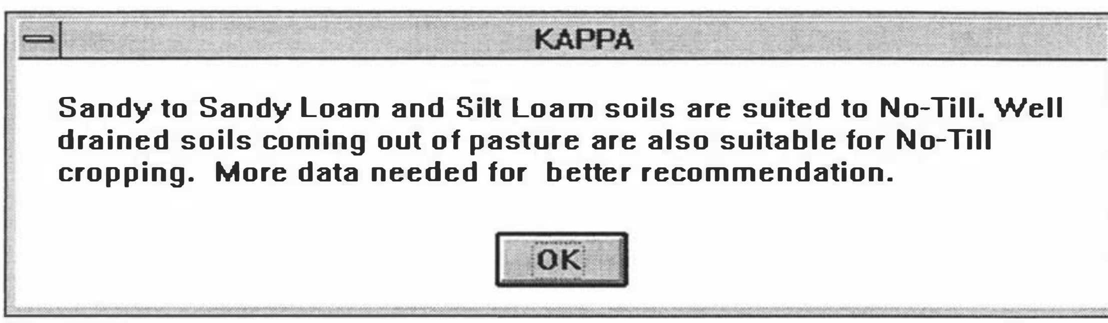

Figure 9

Or, if only crop rotation and the slope values were entered, the message would read as follows:

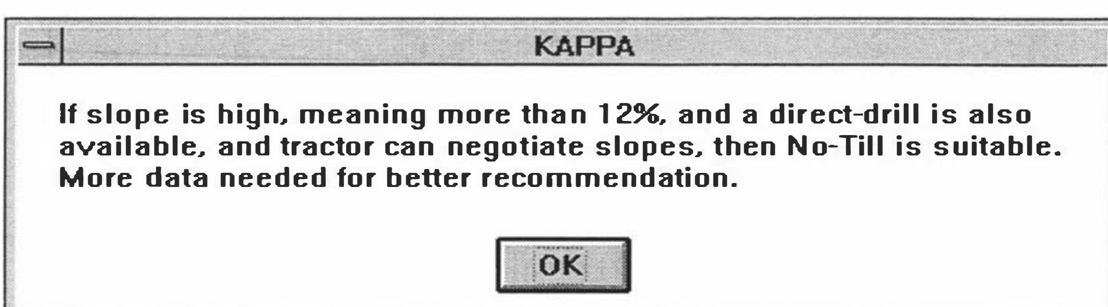

Figure 10

PART-II

NOTE contains rules which can run in the "backward" direction too. It means, if the user likes to know what conditions should suit No-Till (or Conventional Tillage Techniques), in the rice or cotton-wheat rotation in Pakistan, and the pasture-cereal or pasture over-drilling situation in New Zealand. The following steps are involved:

Step 1

After completing Steps 1 and 2 of the PART-I, (for example, the user opts for Pakistani Rice-Wheat situation) and the file PKR.kal (Pakistan-Rice) is in operation. Figure 11 should appear on the screen:

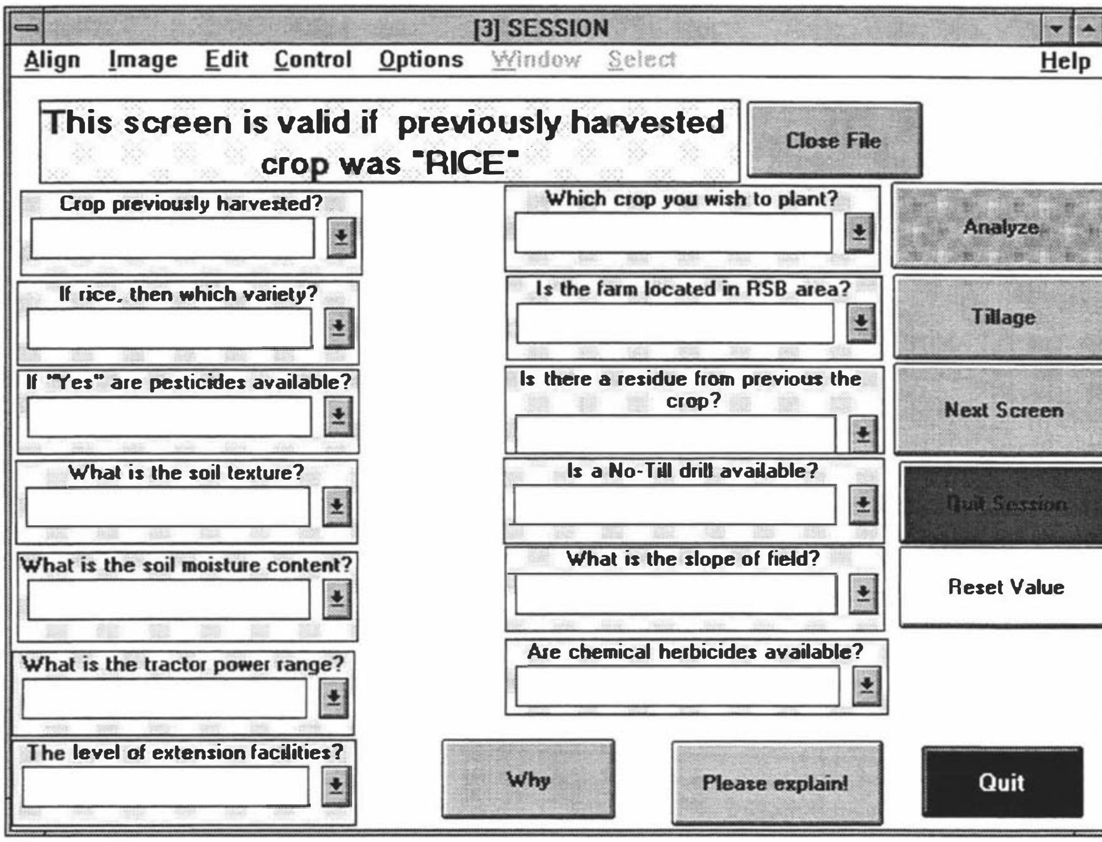

Figure 11

The user should then click the button titled "Tillage". Two options as shown in the Figure 12 should appear. User should enter one of the options in the dialogue box. Let us assume that the user has opted for "Conventional Tillage".

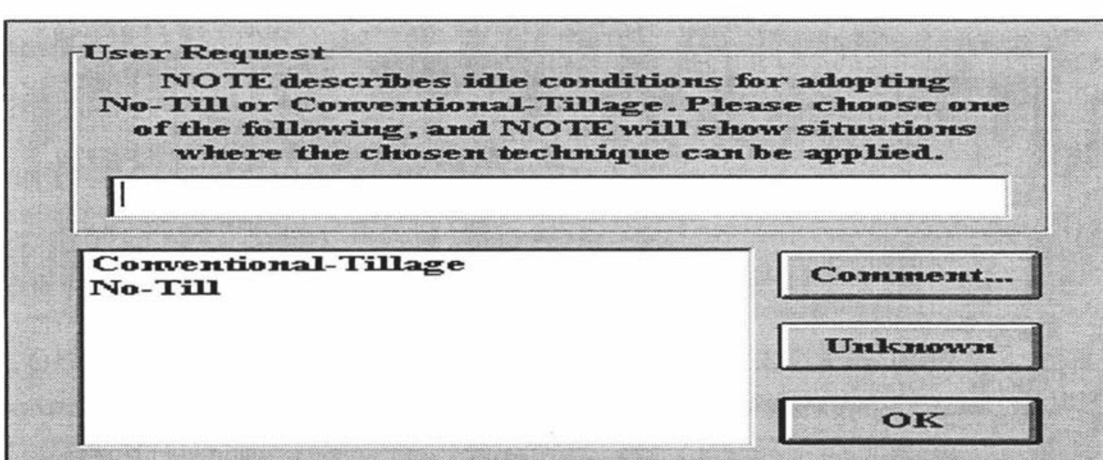

Figure 12

NOTE will start describing the suitable values conditions when the farmer should continue with the conventional tillage techniques. Some of the messages would read as in Figure 13:

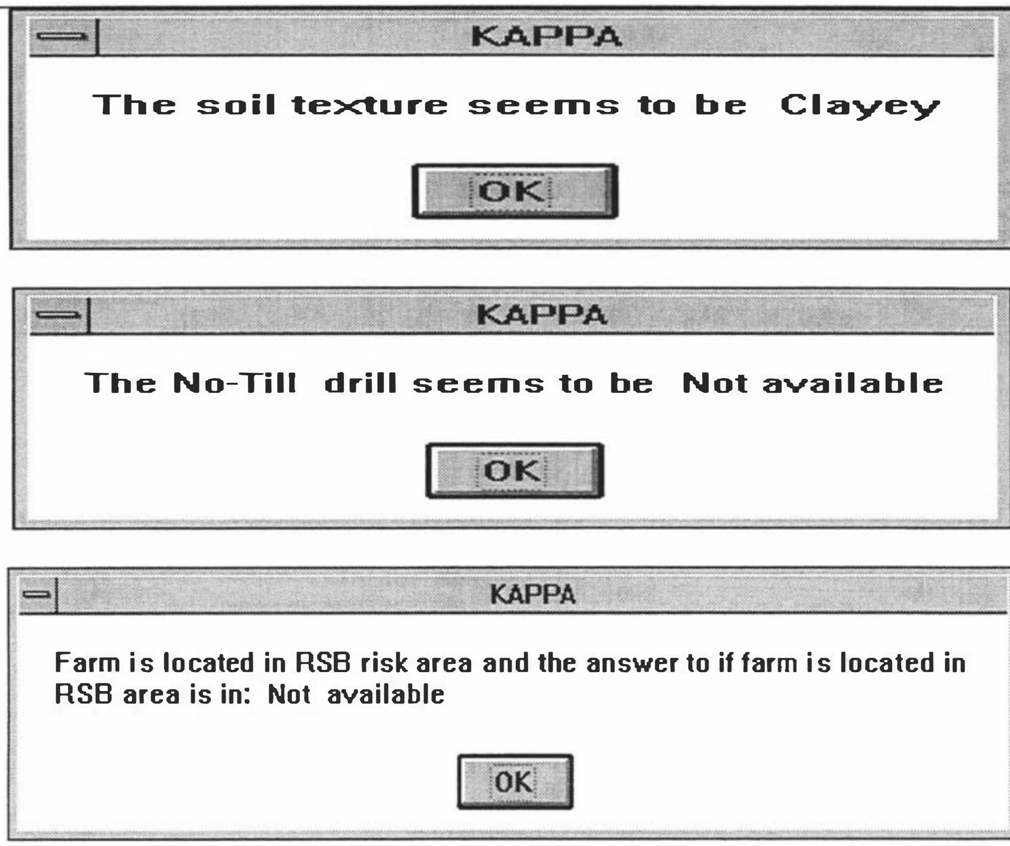

Figure 13

Step 2

These values will automatically be filled in the dialogue boxes (Figure 11). A Microsoft Word file will be generated and if the user wishes, its print can be obtained by following few instructions mentioned on the screen.

4.2 Other features of NOTE

4.2.1 Please explain!

Once on the main application of NOTE (i.e. Figure 6 or Figure 11), the user can retrieve more information on the various aspects of input variables used in the decision making process. For example, from Figure 6 or Figure 12, if the button box titled "Please explain" is clicked, the user comes to a screen that appears as in Figure 14. Pressing button "Next Crop ?", prompts a reference that was used in making rule(s) related to crop rotation (Figure 15). The next screen (Figure 16) asks the user if more information is required. Selection of "Yes" in the dialogue box takes the user to a Microsoft Word file (Figure 17) describing further information as to how the rules related to crop rotations were constructed.

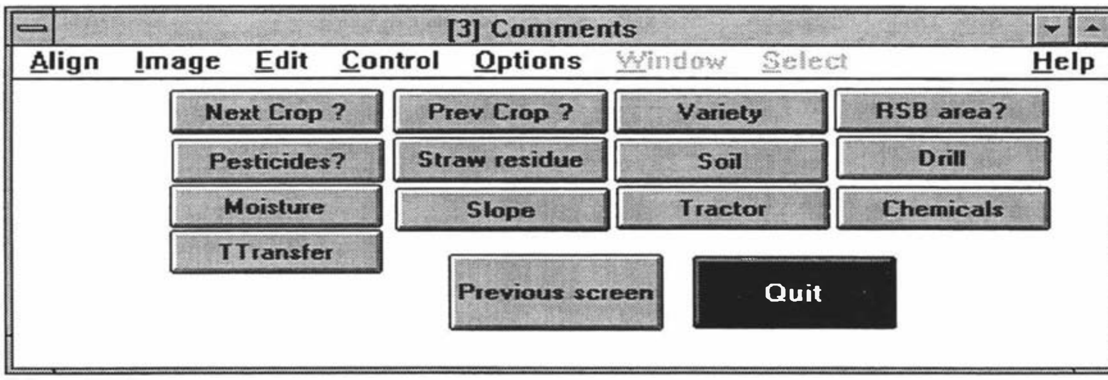

Figure 14

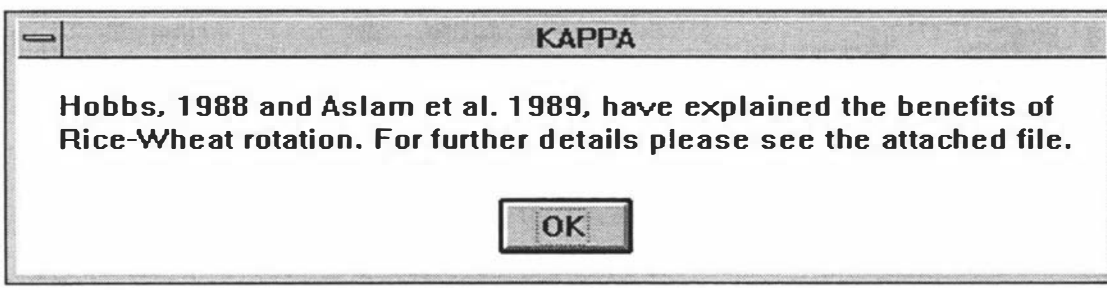

Figure 15

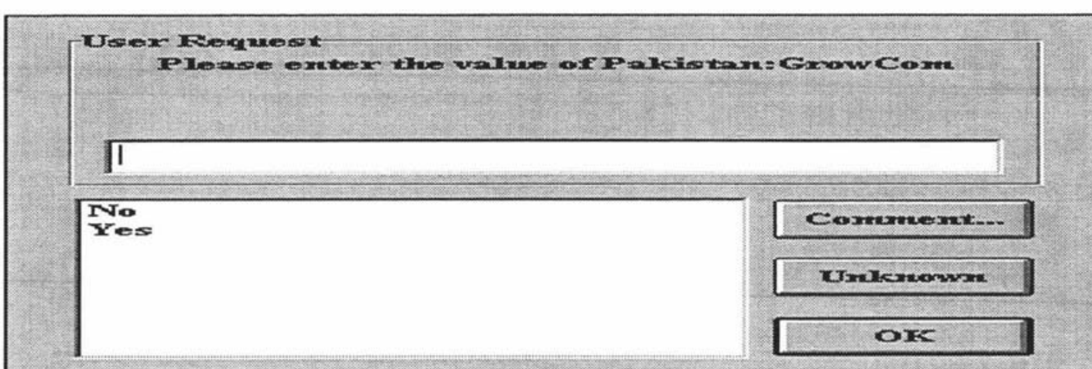

Figure 16

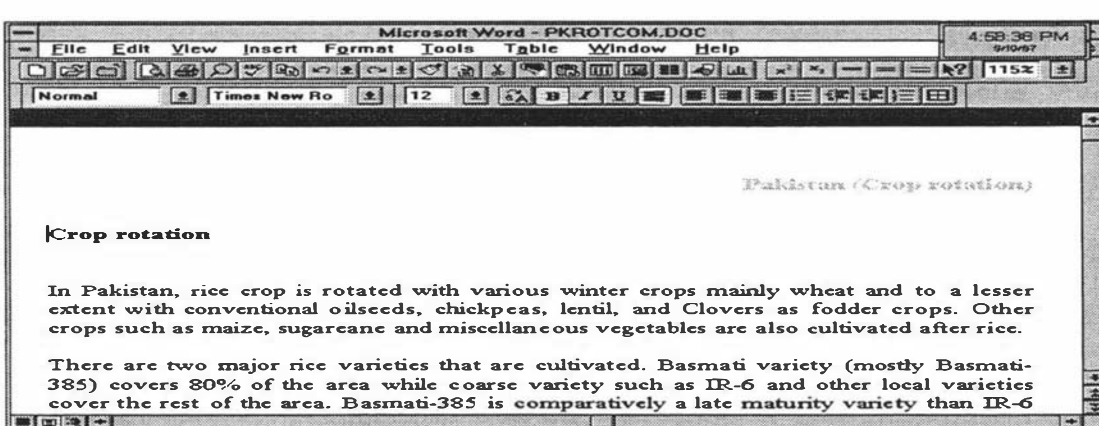

Figure 17

4.2.2 Reset Value

Once the user wishes to re-enter the data, the button named "Reset Value" wipes all data previously entered in the dialogue boxes. It is recommended to press this button with every new application. Thus, clicking this button enables the user to avoid any wrong data entry for the next application.

4.2.3 Quit

Pressing "Quit" button is a faster way of closing the current application file of NOTE. Before quitting, it asks the user if the current file needs to be saved. NOTE over-writes the currently run file if the name is not changed, though it re-confirms if the user wants to over-write the file.

4.2.4 Changing Word processing file for printing results

As mentioned in Section 3, with the current set-up, the result of a recommendation are generated and saved in a Microsoft Word file. However, following steps are involved if the user wishes to generate the results in a WordPerfect file:

Step 1

From the "Edit Tools" (Figure 18) application, choose the "Function" button.

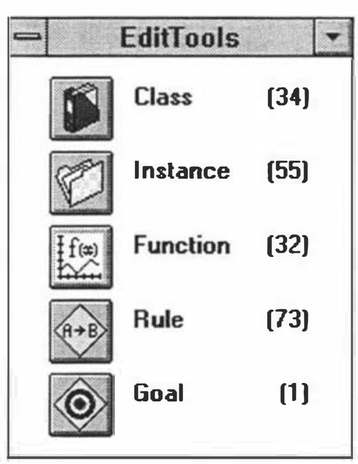

Figure 18

Step 2

Edit and save the functions named as "Backward" and "Test", which currently read as under:

Backward:

```
{OpenWriteFile(NZC.doc); ............ CloseWriteFile( ); ....................
PostMessage ("If you want to print this report please go into programme manager (file
manager) and retrieve the file named 'NZC.doc'. Then print it.");};
```

Please change "**.doc**" to "**.wpd**" at both locations.

NOTE will now generate a "WordPerfect" file. Similarly, changing the word "**.doc**" to "**.wri**" enables user to get results in a file with an extension ".wri".

Test:

The function "test" currently reads as under:

{OpenWriteFile(NZCAn.doc); .... CloseWriteFile( ); .... PostMessage ("If you want to print this report please go into programme manager (file manager) and retrieve the file named 'NZCAn.doc'. Then print it.");};

Please change "**.doc**" to "**.wpd**" at both locations.

NOTE will now generate a "WordPerfect" file. Similarly, changing the word "**.doc**" to ".wri" enables the user to get results in a file with an extension "**.wri**".

The file produced will be a "Wordperfect" file. Changing "**.doc**" to "**.wri**" enables the user to get results in files with extension ".wri".

4.2.5 Editing Rules

NOTE consists 472 rules placed in various sections which are not attached in this user guide. Should a need arise to edit any of the rules, the user should go to the "Edit Tools" window (Figure 18). These rules appear in an alphabetical order once the "Rule" icon is clicked in the "Edit Tools". Once edited, the rule should again be saved. However, if the rule is saved under a new name, (or a new rule is created) the user should make sure that it is added in the respective "Function" list, otherwise it will not trigger during the decision making process of NOTE.

4.2.6 Other Help Files and Commands

Like other softwares, the Kappa-PC also has its own range of "Help" directory. Once, NOTE is running, the user is able to seek help by retrieving the respective portion of the Kappa-PC by pressing the "Help" icon.

2

Getting Started

Presently NOTE is set to run on a PC with Microsoft Word. If your PC does has some other writing program, please follow the instructions in the user guide section 4.2.4.

1. Load Kappa-PC (Two disks provided)
2. Load NOTE in Kappa directory (Two disks provided)
3. Open Kappa-PC and a file named "Country.kal"
4. Follow instructions on screen